ADDITIONS TO THE MIOCENE FLORAS OF SOUTHWESTERN HOKKAIDO, JAPAN

by

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(with 3 text-figures and 8 plates)

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Contents

Abstract

The Miocene sediments of southwestern Hokkaido include a number of

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well-preserved plants at various localities, and six floras of Early and Middle Miocen ages were already described. The authors have investigated Miocene floras from several new localities, and add further two floras, the Kudo and the Garo, to the previous report. These floras studied here are found in the "Kudo" sheet map area (1:50,000).

The Kudo flora is found in the siltstone intercalations of Middle Miocene basaltic lava near Kudo village, Taisei-mura. It is composed mainly of temperate deciduous hardwoods, with associated several conifers. Considering from frequency records of fossil plants and the distribution of their modern related species, the Kudo flora represents the deciduous hardwood forest which lived on valley and somewhat high slopes during the Middle Miocene age. The Garo flora is included in the Futoro formation along the Garo river, Kitahiyama-cho, which is correlated to the Lower Miocene Fukuyama formation. It is composed of temperate deciduous hardwoods and conifers, and is characterized by the abundance of montane conifers. The paleoecological analysis shows that the Garo flora represents the mixed conifer-hardwood forest lived at somewhat higher altitudes during Early Miocene age. Furthermore, the Wakamatsu flora previously reported is discussed on its floral composition, based on additional collection from three new localities.

Introduction

The Miocene sediments accompanying with abundant pyroclastic rocks are widely distributed in southwestern Hokkaido. The lower part of them interbeds frequently fluvio-lacustrine or neritic sediments yielding well-preserved plant fossils. The author once described six Miocene floras in this region, and discussed in detail on their floristic composition and paleoecology (TANAI, 1963). It was revealed that these six floras represent the typical temperate vegetations of northern Japan during Early and Middle Miocene age, and that the Middle Miocene vegetation contains less evergreen broad-leaved trees than that of Honshu. From the comparison among Middle Miocene floras of Hokkaido and Honshu, it may be possible to reconstruct the Miocene latitudinal distribution of vegetation as well as the altitudinal distribution.

The senior author has continued to investigate the Miocene floras of southwestern Hokkaido; in 1966 he collected a number of well-preserved plant fossils at several new localities, which were found out by the staffs of the Geological Survey of Japan. As these floras newly found are especially significant for Miocene stratigraphy of southwestern Hokkaido, the authors visited there again in the years of 1970 and 1971 to collect a sufficient materials. It is the purpose of this paper to describe two floras newly found in this region, and to discuss on floristic composition, compared with six floras already reported.

The authors wish to express their appreciation to Mr. Mitsuo HATA of the Geological Survey of Japan, who gave geological informations on fossil localities and aided to collect fossils in 1966. Thanks are also due to Dr. Seiji SATO of Hokkaido University for his current palynological informations regarding the plant-bearing rocks. This research was financed partly by the Scientific Research funds of the Ministry of Education (no. 584613), which has been given to the senior author.

This article is dedicated to Dr. Toshio ISHIKAWA, Professor of Petrology, Hokkaido University in the commemoration of his retirement, who has devoted much time to investigate on Tertiary volcanology of southwestern Hokkaido.

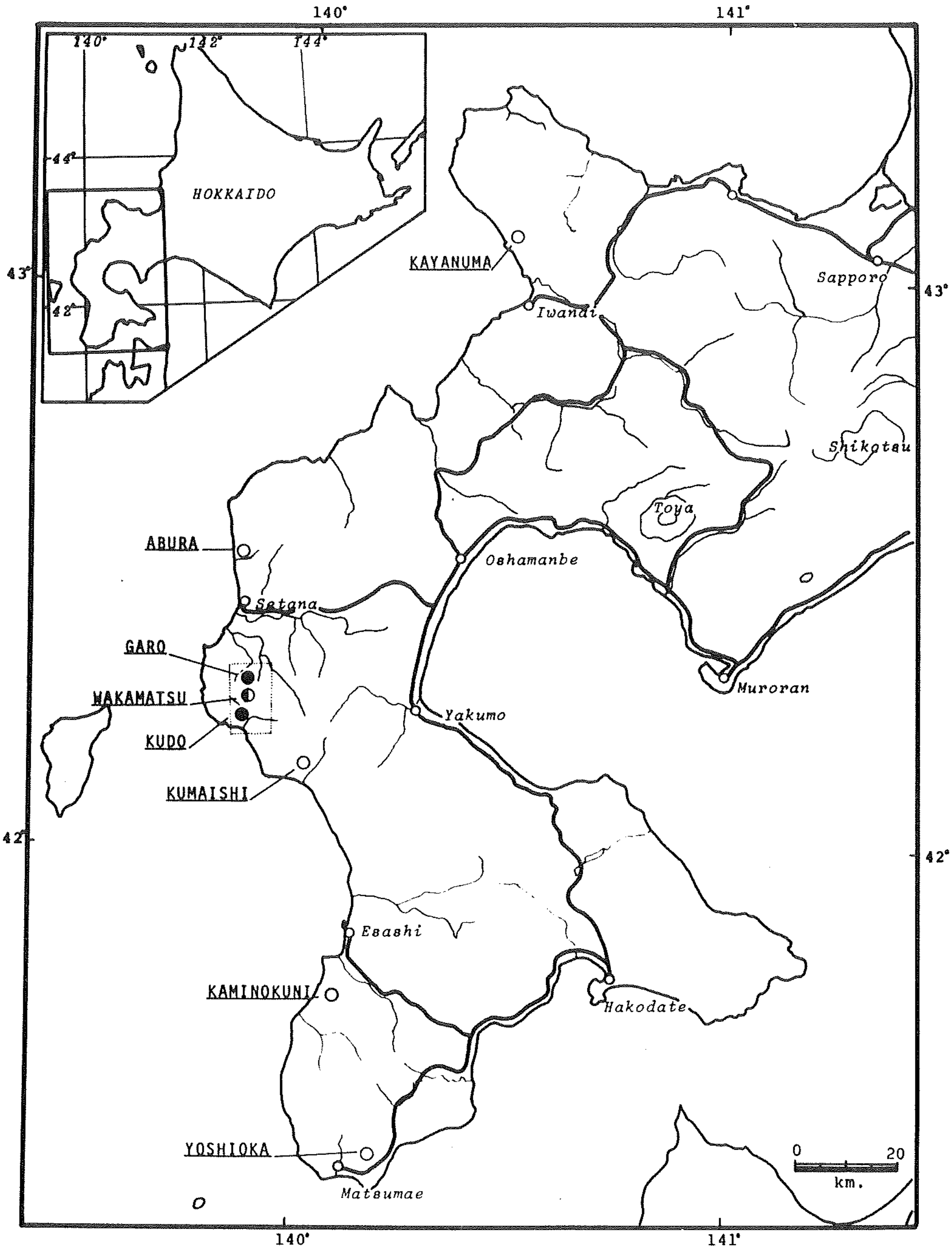
General Geology of the Area

The area which includes the fossil localities occupies the central part of southwestern Hokkaido, and is in the Japanese sheet map "Kudo" (scale 1:50,000). Neogene sediments in this area are widely distributed with a great thickness on Pre-Tertiary basement, which are composed of slate, hard sandstone, chert and hornblende-biotite granodiorite. The fossil flora studied here are shown in Text-figure 1, with the location of the Miocene floras previously described by the authors (TANAI and N. SUZUKI, 1963). The detailed localities of plant fossils are further figured in Text-figure 2.

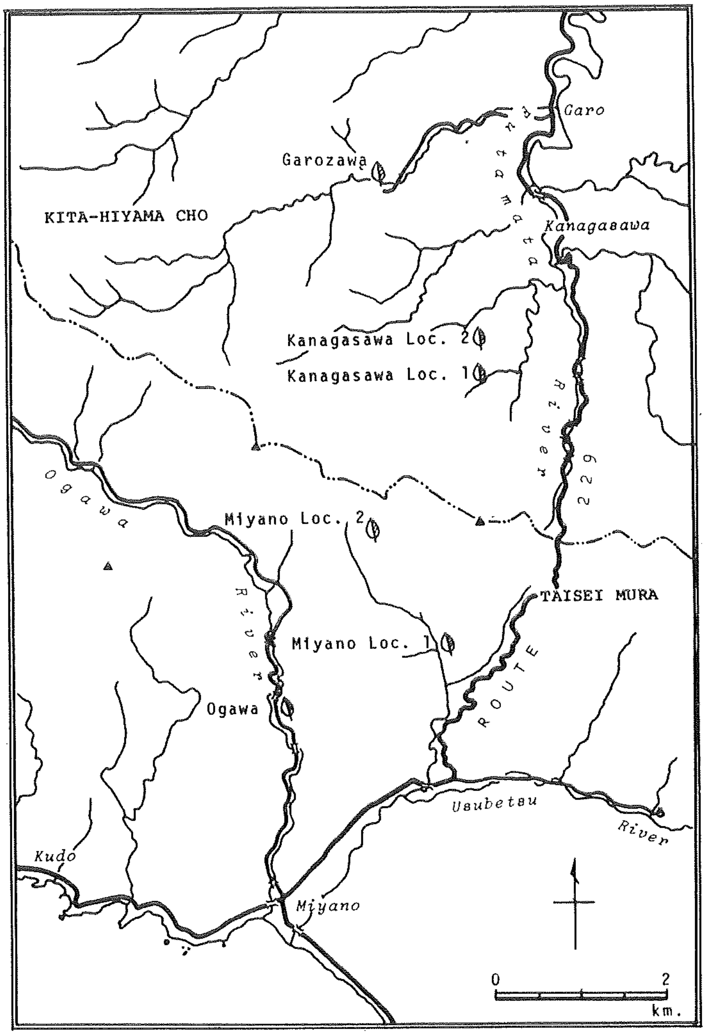
Neogene stratigraphy of this area has not been settled until the recent days, though a number of geological reports have been published (SUZUKI, M. *et al.*, 1969; others). It is mainly due to the facts that the Neogene has abundantly pyroclastic and volcanic rocks, and shows considerably lateral changes in lithology. HATA *et al.* have devoted much time to investigate this area, and recently they established in detail Neogene stratigraphy. Based on their result, the following description is largely made.

The Miocene sediments of this area are divided into five formations, and the Pliocene is divided into two formations as shown in Table 1. This Neogene stratigraphy is correlated with that of the Matsumae-Fukushima area, where the standard Neogene sequence is well established.

The Futoro formation covers the Pre-Tertiary rocks with an angular unconformity, and is composed of abundant pyroclastic rocks such as tuff breccia, propylite and andestic lava. It has frequently intercalations of tuffaceous sandstone and siltstone, rarely with thin lignite seams. It is more than 300 meters thick. The formation contains sometimes plant fossils at several localities, especially in the middle course of the Garozawa river. The Sekinai formation mainly of terrestrial origin is distributed intermittently on the Futoro formation with an unconformity. It consists principally of



Text-figure 1
The Distribution of Miocene Floras in Southwestern Hokkaido.
Black circles: Floras described in this paper.
Half black circle: Flora previously described, which new materials are added.
Open circle: Floras previously described.



Text-figure 2
Plant fossil localities in the Kudo-Kanagasawa Area.

tuffaceous siltstone, associated with sandstone intercalations and lignite seams, and varies from 10 to 200 meters in thickness. A number of well-preserved plant fossils occur from this formation in the Miyano and Kanagasawa area. The Wakamatsu flora previously reported in 1963 was found from this formation.

The Hidarimatagawa formation is widely distributed with more than 1000 meters thickness in this area, and covers unconformably the Futoro and Sekinai formations. The Hidarimatagawa formation is composed of various rocks such as conglomerate, sandstone, siltstone, andestic tuff or tuff breccia, and shows considerable lateral changes in lithology. The formation is mainly of marine origin, and contains a number of molluscs in its upper part. In the Miyano-Kudo area olivine-augite basalt lava is distributed on the Futoro formation, while basalt and its scoria are widely distributed along the Usubetsu river and its northward, interfingered with the Hidarimatagawa formation. Along the Ogawa river of Miyano area basalt lava interbedds sometimes tuffaceous siltstone and sandstone, which contain well-preserved plant fossils.

Table 1 Neogene Stratigraphy of the Kudo-Kanagasawa Area, correlated with the Type Sequence of Southwestern Hokkaido.

area / age	Kudo-Kanagasawa (HATA *et al.*, 1971)	Matsumae-Fukushima
Pliocene	Setana formation	Setana formation
	Nagaiso andesites	
Miocene	Makomanai formation	Kuromatsunai formation
	Mujinatai formation	Yakumo formation
	Hidarimatagawa formation	Kunnui formation
	Sekinai formation*	Yoshioka formation*
	Futoro formation*	Fukuyama formation*
Pre-Tert.	Pre-Tertiary rocks	

*Plant-bearing formation

The Mujinatai formation with about 200 meters thickness is widely distributed on the Hidarimatagawa formation with an angular unconformity, mainly in the northeastern part of this area, and consists of felsic tuff, tuffaceous siltstone and mudstone with intercalations of siliceous shale. The Mujinatai formation is covered by the Makomanai formation, which is composed of diatomaceous siltstone, with many intercalations of tuff and sandstone. These two formations are of marine origin, but contain no well-preserved molluscs.

In the northern part of this area the Setana formation is distributed on the Makomanai formation, and consists mainly of loose sandstone and conglomerate which contain a number of Pliocene well-preserved molluscs. In the southern part of this area the Nagaiso hornblende-andesite covers the Makomanai formation, and is probably of Pliocene age.

The Kudo Flora

Geographic and Geologic Setting

The locality from which the fossil plants were obtained, is located approximately 20 km. south of the Higashi-Setana Station of the Setana railroad line, and is on the southwestern part of the Kudo sheet. The area including the fossil locality occupies the southern part of the so-called Kudo coal-bearing area, where all of the coal mines were abandoned. The locality extends along the cliffs in the lower course of the Ogawa river, situated approximately 3 km. from the Miyano village, Taisei-mura.

Basaltic lava, a member of the Hidarimatagawa formation, is widely developed along the Ogawa River from the coastal area, and have lenticular intercalations of sandstone and siltstone. The plant fossils are found in alternation of tuffaceous siltstone and sandstone with interbedded thin lignite seams; they are especially well-preserved in the siltstone. All of the fossils are mainly represented by leaf impressions, and partly by the reproductive organs such as seeds, fruits, bracts and others.

The surrounding area is in the mountainous region along the Japan Sea, and consists of relatively low mountains with elevations of 200 to 500 meters above the sea level. This area is situated near the northern limit of the beech forest distribution in Japan; the forest of this area consists principally of cool-temperate, deciduous broad-leaved trees. The principal broad-leaved trees are *Acanthopanax sciadophylloides, Acer japonicum, Acer mono, Acer tschonoskii, Alnus hirsuta, Carpinus cordata, Fagus crenata, Fraxinus sieboldiana, Kalopanax pictus, Magnolia obovata, Tilia japonica* and *Ulmus laciniata.* The common small trees and shrubs are *Euonymus macropterus, Cephalotaxus harringtonia* var., *Hydrangea paniculata, Ilex crenata* var., *Rhododendron albrechti, Skimmia japonica* var., *Sorbus commixta, Vaccinium hirtum* and *Viburnum furcatum.* There are commonly found several vines such as *Celastrus orbiculatus, Rhus ambigua, Schizophragma hydrangeoides* and *Vitis coignetiae.* The beech forest of this region was investigated in detail by TATEWAKI (1958). *Fagus crenata* is abundant at lower altitudes (0-500 meters), and is gradually replaced by *Betula ermanii* from more than 500 meters.

Composition of the Flora

The Kudo flora includes 31 species as listed below, comprising one horsetail, five conifers and 25 dicotyledons; all of these species have been already described in the Miocene floras of southwestern Hokkaido or northern Honshu. The species are distributed among 16 families and 22 genera. The largest family is the Aceraceae with one genera and six species, and the next is the Betulaceae with three genera and five species. The remaining families have one or two genera. Most of genera are represented by a single species except for *Acer* with six, *Carpinus* with three, and *Picea* and *Pterocarya* with two each.

Systematic List of Families and Species

Equisetaceae

Equisetum arcticum HEER

Pinaceae

Picea kaneharai TANAI et ONOE

Picea ugoana HUZIOKA

Pinus sp.

Keteleeria ezoana TANAI

Taxodiaceae

Glyptostrobus europaeus (BRONGNIART) HEER

Myricaceae

Comptonia naumanni (NATHORST) HUZIOKA

Juglandaceae

Pterocarya asymmetrosa KONNO

Pterocarya protostenoptera TANAI

Betulaceae

Alnus protomaximowiczii TANAI

Carpinus miocenica TANAI

Carpinus subcordata NATHORST

Carpinus subyedoensis KONNO

Corylus macquarrii (FORBES) HEER

Fagaceae

Fagus antipofi HEER

Ulmaceae

Ulmus carpinoides GOEPPERT

Zelkova ungeri KOVATS

Eucommiaceae

Eucommia japonica TANAI

Cercidiphyllaceae

Cercidiphyllum crenatum (UNGER) BROWN

Liguminosae

Gleditsia miosinensis HU et CHANEY

Pueraria miothunbergiana HU et CHANEY

Anacardiaceae

Rhus miosuccedanea HU et CHANEY

Aceraceae

Acer ezoanum OISHI et HUZIOKA

Acer miohenryi HU et CHANEY

Acer protojaponicum TANAI et ONOE

Acer palaeodiabolicum ENDO

Acer subpictum SAPORTA
Acer yoshiokaense TANAI et N. SUZUKI
Tiliaceae
Tilia protojaponica ENDO
Hydrocaryaceae
Hemitrapa borealis(HEER) MIKI
Oleaceae
Fraxinus wakamatsuensis TANAI et N. SUZUKI
Insertae Sedis
Carpolithes japonica (MORITA) ISHIDA

Similar as most of the Miocene floras already reported from southwestern Hokkaido, the Kudo flora is well represented by temperate families such as the Pinaceae, Juglandaceae, Betulaceae, Ulmaceae and Aceraceae, and contains no evergreen trees. Judging from the foliage and fruiting structures available for study, nearly all of the fossils appear to be closely similar to the living plants. Compared with their living equivalents, their probably growth habit is generally determined. There are 25 different species of trees, four shrubs and two herbs.

To the megfossil list may be added a microfossil list based on the current studies by S. SATO. From lignite and plant-bearing siltstone at same locality, a number of spores and pollen belonging to many genera or families have been found, as shown in the following list.

List of Microfossils

Pinaceae
indet. genera*
*Tsuga**
Taxodiaceae*
Myricaceae*
Myrica
Salicaceae
Salix
Juglandaceae
Carya
Juglans
*Pterocarya**
Betulaceae
*Alnus**
Betula
*Carpinus**
*Corylus**
Fagaceae
*Fagus**
Quercus
Ulmaceae
*Ulmus** or *Zelkova**
Anacardiaceae
*Rhus**?
Aquifoliaceae
Ilex
Aceraceae
*Acer**
Tiliaceae
*Tilia**

Starred genera and families are represented also by megafossils in the Kudo flora. The microfossil record shows a close similarity in floral composition to the megafossil record, although some genera such as *Salix, Carya, Juglans* and

Quercus are not found in the megafossils.

The quantitative appraisal of the Kudo megaflora is based on a count of 481 identifiable specimens from one locality, as shown in Table 2. The first 11 species making up more than two per cent each, combined to constitute about 90 per cent of the total. All of these species are trees except two species of *Comptonia naumanni* and *Hemitrapa borealis.* The first four species in Table 2 comprise nearly 64 per cent of the fossils collected, and appear to have lived near the sites of deposition. The abundance of *Fagus* and *Comptonia* is especially significant; these two species make up about 42 per cent of the total, although their closest living species now inhabit in the temperate forest of eastern North America. Two species of *Picea* represented only by winged seeds, were probably transported into the sites of deposition by wind or water-stream from somewhat distant area. *Carpinus* and *Acer* are mostly represented by both leaves and seeds or bracts, and their abundant occurrence may show that they were dominant members in the Kudo forest.

Table 2. Numerical Representation of Kudo Species

Species	Number of specimens	Percentage
Fagus antipofi	145	30.1
(leaves)	(137)	
(involucres)	(4)	
(bud-scale)	(2)	
Comptonia naumanni	60	12.4
Acer ezoanum	54	11.2
(leaves)	(31)	
(samaras)	(23)	
Zelkova ungeri	47	9.8
Picea kaneharai (winged seeds)	30	6.3
Alnus protomaximowiczii	21	4.4
Acer subpictum	19	4.0
(leaves)	(5)	
(samaras)	(14)	
Picea ugoana (winged seeds)	18	3.8
Carpinus subyedoensis	13	2.7
(leaves)	(12)	
(bract)	(1)	
Carpinus subcordata	11	2.3
(leaves)	(7)	
(bract)	(1)	
(nutlets)	(3)	
Hemitrapa borealis (nuts)	10	2.1
Acer miohenryi	7	1.5
(leaves)	(6)	

(samara)	(1)	
Eucommia japonica	6	1.3
(leaf)	(1)	
(winged seeds)	(5)	
Corylus macquarrii	5	1.0
(leaves)	(4)	
(nut)	(1)	
Acer yoshiokaense (samara)	5	1.0
Equisetum arcticum (stems)	4	0.8
Gleditsia miosinensis	3	0.6
Acer palaeodiabolicum	3	0.6
Keteleeria ezoana	2	
(leaf)	(1)	
(staminate cone)	(1)	
Glyptostrobus europaeus	2	
(foliage shoots)		2.5
Pterocarya asymmetrosa	2	
Pterocarya protostenoptera	2	
Cercidiphyllum crenatum	2	
Tilia protojaponica (bracts)	2	
Pinus sp.	1	
Carpinus miocenica	1	
Ulmus carpinoides	1	
Pueraria miothunbergiana	1	
Rhus miosuccedanea	1	1.6
Acer protojaponicum	1	
Fraxinus wakamatsuensis	1	
(winged seed)		
Carpolites japonica	1	
Total specimens	481	100.0

Note: Unless otherwise stated, the organs recorded are leaves or leaflets.

According to Dr. SATO's current investigation, pollen grains of the Pinaceae (except *Tsuga*), *Alnus* and *Fagus* are dominated in microfossil record. They are followed by pollen of the Taxodiaceae, *Ulmus* or *Zelkova, Tsuga, Carpinus, Corylus* and *Carya.* Excepting for *Acer* and *Hemitrapa,* the relative abundance of the Kudo microfossil records is generally consistent with that of the megafossils. It has been pointed out that pollen of *Acer* is not suitable for preservation in sediments. The extinct genus *Hemitrapa* is unknown in its pollen form.

It may be concluded that many deciduous broad-leaved trees, especially beech, maples, hornbeams, *Zelkova,* alder and sweet-fern were dominant members of the forest near the sites of deposition; most of them are represented by both leaves and reproductive organs. It is noteworthy that *Metasequoia* has been not yet found in the Kudo flora, though it is common in the Miocene of Japan.

Distributional Considerations

The Kudo flora including the microflora, consists mostly of temperate genera which are largely confined to middle latitudes. Two conifers, *Keteleeria* and *Glyptostrobus,* are living in the subtropical region of southern China; but *Keteleeria* occupies high altitudes and extends northward into west-central China. Some angiosperm genera such as *Myrica, Quercus* and *Ilex,* represented only by pollen, range well to the south, but they comprise southern group which regularly extends into temperate altitudes and latitudes. All of the Kudo genera including those represented only by pollen, are now distributed in East Asia, with the exception of *Comptonia* living in eastern North America. These East Asiatic genera are still living in Japan, excepting *Carya, Glyptostrobus, Keteleeria* and *Eucommia;* the first is living in China and the eastern United states; the latter three living in China.

Table 3 give a list of the Kudo plants with their nearest living species and their modern distribution. The plants represented only by pollen are excluded in this list, because Tertiary pollen is generally not assignable in the specific relationships with the modern plants. Two harbaceous species, *Equisetum* and *Hemitrapa,* are also excluded. On the basis of modern specific relationships, the Kudo plants fall mostly in the East Asian Elements, with 25 species making up about 86 per cent of the species. All of the conifers are East Asian in their modern relationships; the angiosperms also fall largely in the East Asian Elements, and only a few species in the East American Elements.

The East Asian Elements

As shown in Table 3, the modern equivalents of the Kudo species are most abundantly concentrated in the temperate forest from northern Honshu to Kyushu in Japan, and also from northern to central China. Nearly all of the Kudo species is already described from the Miocene floras of southwestern Hokkaido by authors (TANAI and N. SUZUKI, 1963). The East Asian Elements of these Miocene floras was discussed in detail in the previous report (TANAI, 1963), and it seems unnecessary to consider at length the occurrence of the modern equivalents of the Kudo flora in East Asia.

The abundance of *Fagus antipofi* and *Zelkova ungeri* in the fossil record shows that the Kudo flora is similar to the deciduous broad-leaved forest at lower and middle altitudes in northern Kwanto and central Honshu. In these regions the so-called "*Castanea* zone forest" occupies lower mountain slopes and valley slopes at alititudes from 600-700 meters up to 1,200-1,300 meters. Though lacking *Castanea,* the following Kudo species find their close living

Table 3 The Modern Equivalents of the Kudo Plants and their Distribution in East Asia and North America

Fossil Species	Modern Equivalents	East Asia													North Amer.	
		Japan						China								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Picea kaneharai	*P. neoveitchii*									X			X			
Picea ugoana	*P. bicolor*				X											
Pinus sp.	*P. densiflora*			X	X	X	X		X							
Keteleeria ezoana	*K. davidiana*							X			X	X	X			
Glyptostrobus europaeus	*G. pensilis*												X			
Comptonia naumanni	*C. peregrina*															X
Pterocarya asymmetrosa	*P. rhoifolia*			X	X	X	X			X						
Pterocarya protostenoptera	*P. stenoptera*									X	X	X	X			
Alnus protomaximowiczii	*A. maximowiczii*	X	X	X	X				X					X		
Carpinus miocenica	*C. laxiflora*		X	X	X	X	X				X					
Carpinus subcordata	*C. cordata*		X	X	X	X	X		X	X	X			X		
Carpinus subyedoensis	*C. tschonoskii*			X	X	X	X		X		X					
Corylus macquarrii	*C. heterophylla*		X	X	X	X	X									
Fagus antipofi	*F. grandifolia*															X
Ulmus carpinoides	*U. davidiana*								X	X				X		
Zelkova ungeri	*Z. serrata*			X	X	X	X		X		X		X			
Eucommia japonica	*E. ulmoides*										X					
Cercidiphyllum crenatum	*C. japonicum*		X	X	X	X	X			X	X	X				
Gleditsia miosinensis	*G. sinensis*									X	X		X			
Pueraria miothunbergiana	*P. thunbergiana*		X	X	X	X	X		X	X	X					
Rhus miosuccedanea	*R. succedanea*			X	X	X	X	X			X	X	X			
Acer ezoanum	*A. miyabei*		X	X												
Acer miohenryi	*A. henryi* (negundo)										X					(X)
Acer protojaponicum	*A. japonicum*		X	X	X	X	X									
Acer palaeodiabolicum	*A. diabolicum*		X	X	X	X	X									
Acer subpictum	*A. mono*	X	X	X	X	X	X		X	X	X	X		X		
Acer yoshiokaense	*A. saccharum*															X
Tilia protojaponica	*T. japonica*		X	X	X	X	X				X					
Fraxinus wakamatsuensis	*F. lanceolata*															X
Number of Nearest Species		2	11	16	16	14	14	2	8	9	14	5	7	4	0	4

1. Saghalien, Kurile Islands.
2. Hokkaido.
3. Northern Honshu.
4. Central Honshu.
5. Southern Honshu.
6. Kyushu and Shikoku.
7. Formosa and Loochoo Islands.
8. Korea.
9. North China.
10. Central China.
11. Southwest China.
12. Southeast China.
13. Manchuria.
14. Western North America.
15. Eastern North America.

species in the "*Castanea* zone forest" of central Honshu.

Kudo flora	Castanea zone forest of Honshu
Pinus sp.	*P. densiflora*
Juglans-pollen	*J. ailanthifolia*
Pterocarya asymmetrosa	*P. rhoifolia*
Betula-pollen	*B. grossa*
Carpinus miocenica	*C. laxiflora*
Carpinus subcordata	*C. cordata*
Carpinus subyedoensis	*C. tschonoskii*
Corylus macquarrii	*C. heterophylla*
Fagus antipofi	**F. japonica*
Ulmus carpinoides	**U. davidiana* var.
Zelkova ungeri	*Z. serrata*
Cercidiphyllum crenatum	*C. japonicum*
Pueraria miothunbergiana	*P. thunbergiana*
Rhus miosuccedanea	**R. silvestris*
Ilex-pollen	**I. geniculata*
Acer miohenryi	**A. cissifolium*
Acer palaeodiabolicum	*A. diabolicum*
Acer protojaponicum	*A. japonicum*
Acer subpictum	*A. mono*
Tilia protojaponica	*T. japonica*
Fraxinus wakamatsuensis	**F. sieboldiana* var.

*Similar species though not nearest equivalent.

The *Castanea* zone gradually passes into the *Fagus* zone at the elevation between 1800-2200 meters in central Honshu, which forest is characterized by dominance of *Fagus crenata.* Most of the above-listed species extend up into the *Fagus* zone forest, excluding several species such as *Zelkova, Fagus japonica, Pinus densiflora* and others. On the one hand, several subalpine plants are mixed with the typical members of the *Fagus* zone in its upper part; some similar subalpine plants such as *Picea polita (P. kaneharai), P. bicolor (P. ugoana)* and *Alnus maximowiczii (A. protomaximowiczii)* in this mixed zone forest. These two spruces are represented only by winged seeds, though showing high scores in fossil occurrence; they appear to have lived at higher altitudes. On the other hand, alder represented only by leaves shows a high percentage in fossil record, and it may be considered to have been distributed at lower altitudes than those of its modern equivalent.

The Kudo flora contains several characteristic species such as *Keteleeria ezoana, Pterocarya protostenoptera, Eucommia japonica* and others, which modern equivalents are now distributed in the deciduous broad-leaved forest of central China. Though the evergreen broad-leaved trees are quite absent, the Kudo flora shows a close resemblance to the Mixed Mesophytic Forest along the Yangtze Valley, as shown in Table 4. The Mixed Mesophytic Forest generally occurs at the elevation of 500-1500 meters in the Lower Yangtze, and at the elevation of more than 1500 meters in the Upper Yangtze.

Table 4 Modern Equivalents in the Slope forest along the Yangtze Valley and its northward

Kudo flora	Mixed Mesophytic Forest: Lower Yangtze	Mixed Mesophytic Forest: Upper Yangtze	Mixed Northern Hardwood Forest
Pinus sp.	**P. massoniana*	**Pinus* spp.	**Pinus* spp.
Keteleeria ezoana	**K. fortunei*	*K. davidiana*	
Carya-pollen	*C. cathayensis*	*C. cathayensis*	*C. cathayensis*
Juglans-pollen	*J. cathayensis*	*J. cathayensis*	*J. regia*
Pterocarya asymmetrosa		**P. insignis*	
Pterocarya protostenoptera	*P. stenoptera*	*P. stenoptera*	*P. stenoptera*
Betula-pollen	*B. luminifera*	*B. luminifera*	
Carpinus miocenica	*C. laxiflora*	*C. laxiflora*	
Carpinus subcordata	*C. cordata*	*C. cordata*	*C. cordata*
Corylus macquarrii		*C. chinensis*	*C. chinensis*
Fagus antipofi	**F. longipetiolata*	**F. longipetiolata*	
Ulmus carpinoides	**U. davidiana*		**U. davidiana*
Zelkova ungeri	*Z. sinica*	*Z. sinica*	*Z. sinica*
Eucommia japonica	*E. ulmoides*	*E. ulmoides*	
Cercidiphyllum crenatum	*C. japonicum*	*C. japonicum*	
Gleditsia miosinensis			*G. sinensis*
Pueraria miothunbergiana			*P. thunbergiana*
Rhus miosuccedanea	*R. succedanea*	*R. succedanea*	
Acer miohenryi	*A. henryi*	*A. henryi*	
Acer subpictum	*A. mono*	*A. mono*	*A. mono*
Tilia protojaponica	*T. japonica*	**T. nobilis*	**T. amurensis*
Fraxinus wakamatsuensis	*F. chinensis*	*F. chinensis*	*F. chinensis*

*More distantly related species

Northward from the Yangtze Valley, the deciduous broad-leaved forest is widely distributed with a transitional zone, and is designated as the Mixed Northern Hardwood Forest by WANG (1961). Though some genera such as *Keteleeria* and *Eucommia* are not represented, this forest contains many species similar to the Kudo plants, as shown in Table 4. *Picea kaneharai* shows a common occurrence in the fossil record, and is closely similar to *P. neoveitchii* which is living in the montane region of northwestern China. The Kudo flora contains *Glyptostrobus europaeus*, though an uncommon member. Its modern similar species, *G. pensilis*, inhabits the lowlands of Canton and Fukien provinces, southeastern China. As discussed in the case of the Miocene Abura flora of southwestern Hokkaido (TANAI, 1963), *G. pensilis* is a tree of moist river borders rather than a swamp inhabitant such as *Taxodium distichum* of the eastern United States. Considering its rare occurrence and the habitat of its associated trees, *G. europaeus* may be supposed to have extended its range up from the lower valley during Miocene time.

From this discussion of the distribution in East Asia of modern plants which is similar to the Kudo species, and which may be supposed to have occupied similar environments, it may be concluded that the Kudo flora contains no typically lowland tree, and represents a forest developed from the valley to lower mountain slopes. Judging from relatively high scores of some montane trees, largely represented by winged seeds, it may be supposed that the high mountains were not distant from the sites of deposition.

The North American Elements

The plants assigned to the North American Elements in Table 3 include only 4 dicotyledons, but most of them show high representation in fossil counting. Especially, the abundance of *Fagus antipofi* is suggestive to show some resemblance to the modern forest of the Appalachian Mountains. If some of less closely similar species are included, the resemblance is further accentuated. The Kudo equivalents include the following characteristic Appalachian plants: *Carya* spp. *(Carya*-pollen), *Carpinus caloriniana (C. miocenica), Fagus grandifolia (F. antipofi), Ulmus americana (U. carpinoides), Gleditsia triacanthos (G. miosinensis), Acer negundo (A. miohenryi), Acer saccharum (A. yoshiokaense), Tilia americana (T. protojaponica)* and *Fraxinus lanceolata (F. wakamatsuensis). Comptonia peregrina* is closely similar to *C. naumanni* which is abundant in fossil record, and it is common on stony uplands and dry pastures from southern Canada to the northeastern United States.

Comparison of the Kudo flora with forests living in eastern North America indicates that it is similar to the Mixed Mesophytic forest of the Appalachian Mountain slopes, and that it contains no lowland tree. This conclusion is consistent with those involving comparison with the forest of East Asia, in which slope forest resemblance is most pronounced.

The Kudo Plant Communities

By taking into account the frequency records of fossil species in the flora, and the distribution of the modern related plants as reviewed above, the Kudo species may be grouped into four communities, which were probably distributed about the basin of deposition. Some of the species contributed to more than one community, as do similar plants today.

Aquatic or Swamp Vegetation

Only two species, *Hemitrapa borealis* and *Equisetum arcticum*, belong to this community, and they appear to have been confined to areas of shallow water along the lake-shore, considering from the habitat of their modern equivalents. *Glyptostrobus europaeus* may be included in the swamp vegetation. But, as already discussed, *G. europaeus* have been probably rather on the stream banks during the Kudo time, judged from their rare occurrence. The uncommon occurrence of swamp plants may indicate that no wide swampy area was developed around the sites of deposition. It is consistent with the fact that only thin lignite seams are lenticularly included in the plant-bearing formation.

Lake-border and Riparian Vegetation

Only six species are included in this community: they are *Equisetum arcticum, Glyptostrobus europaeus, Corylus macquarrii, Acer miohenryi, Gleditsia miosinensis* and *Fraxinus wakamatsuensis.* Judging from the habitat of their living analogues, all of these plants appear to have favoured wet soil. It is noteworthy that all of these species, excluding *Acer miohenryi,* show low representation in fossil record. Most members of this community were not confined to the lake-shore and stream banks, and probably ascended upward into well-watered valley flats and lower valley slopes.

Valley Forest

Nearly two-third species of the total Kudo plants are included in this community, and they are mesic to near-hydric plants which lived on well-drained, moist, valley sites. They are the following 20 plants:

Acer ezoanum	*Fagus antipofi*
Acer subpictum	*Fraxinus wakamatsuensis*
Acer miohenryi	*Gleditsia miosinensis*
Acer palaeodiabolicum	*Pterocarya asymmetrosa*
Carpinus subcordata	*Pterocarya protostenoptera*
Carpinus subyedoensis	*Pueraria miothunbergiana*
Cercidiphyllum crenatum	*Rhus miosuccedanea*
Comptonia naumanni	*Tilia protojaponica*
Corylus macquarrii	*Ulmus carpinoides*
Eucommia japonica	*Zelkova ungeri*

Of the trees and shrubs listed in this community, several species showing very high representation, such as *Acer ezoanum, Acer subpictum, Carpinus subcordata, Carpinus subyedoensis, Comptonia naumanni, Fagus antipofi* and *Zelkova ungeri,* probably lived at the most luxuriant growth in this community. Especially the latter three, *Comptonia, Fagus* and *Zelkova* may have grown luxuriantly on the well-drained, valley flats such as valley bottom and stream border, hilly area and lower valley slopes. On moist tracts, *Acer miohenryi, Corylus macquarrii, Fraxinus wakamatsuensis* and *Ulmus carpinoides* probably lived, though not common.

Slope Forest

This community consists of 18 trees, of which 12 species are also the members of the valley forest. All the members are the deciduous broad-leaved trees, excluding two conifers, as follows:

Keteleeria ezoana	*Carpinus subcordata*
Pinus sp.	*Carpinus subyedoensis*
Acer ezoanum	*Cercidiphylhum crenatum*
Acer subpictum	*Comptonia naumanni*
Acer palaeodiabolicum	*Eucommia japonica*
Acer protojaponicum	*Fagus antipofi*
Acer yoshiokaense	*Pterocarya asymmetrosa*
Alnus protomaximowiczii	*Tilia protojaponica*
Carpinus miocenica	*Zelkova ungeri*

Most of these trees were probably common on the lower slopes. But, judging from the habitat of their living equivalents, some species such as *Acer subpictum, Alnus protomaximowiczii* and *Keteleeria ezoana* appear to have increased in number on higher slopes. Several plants showing low representation in fossil record, such as *Pinus, Tilia, Acer protojaponicum* and *Carpinus miocenica,* may have be uncommon member in the slope forest.

The abundant occurrence of spruce seeds may indicate that these conifers were probably mixed with the broad-leaved trees. The conifer-deciduous hardwood forest was probably composed of the following principal members on the upper slopes and uplands:

Picea kaneharai	*Acer protojaponicum*
Keteleeria ezoana	*Alnus protomaximowiczii*
Acer subpictum	*Carpinus subcordata*

Juding from pollen record, *Tsuga* and *Betula* may be added to the members of the mixed forest.

Summary

From the preceding discussion on the plant community, we may suppose that the Kudo vegetation represents the forest which lived from the lake border to higher slopes, in special mainly from valley sites to lower slopes. It is noteworthy that few species were confined to the lowland and lake-border communites. As described in geologic occurrence of the flora, the plant-bearing rocks are lenticularly interbedded in basaltic lava, and are thinly well-laminated. It may be inferred that valleys were probably dammed by lava flow to form small, local ponds, in which the plant remains were accumulated. Considering the plant communities together with geologic setting, it is concluded that the sites of Kudo deposition were somewhat higher at altitudes (probably more than 500 meters above sea level), and were surrounded by mountain slopes.

Climatic Conditions

In the previous report of six Miocene floras of southwestern Hokkaido, the senior author described in detail on the Miocene climatic conditions at middle altitudes indicated by the flora (TANAI, 1963). Accordingly, in discussing the Kudo climate it seems unnecessary to indicate a good deal evidence to add to the previous report.

The Kudo plants find a number of their analogues in the temperate deciduous hardwood forest of central Honshu, which has been called the *Castanea* zone forest. In this region, as indicated by climatic data at Iida and Takayama at middle altitudes (480-560 meters), there is a mean annual temperature of 10° ~ 12° C., an average winter temperature of –4° ~ –6.5° C., and a mean annual precipitation of 1500-1700 mm. On the one hand, in the interior basins surrounded by mountains such as at Matsumoto and Nagano, the mean annual precipitation, showing about 1000 mm., is lower than in the above-noted places, though temperatures are nearly similar. The Kudo forest is composed of further less deciduous hardwood trees than the modern *Castanea* zone forest of central Honshu at middle altitudes, and also has no warm temperate trees. These facts may indicate that the Kudo climate was probably under somewhat less precipitation than in the slope forest region of central Honshu.

The Kudo flora slso resembles the slope forest along the Yangtze Valley and its northward in central China. The climate of the area along the Yangtze is typically mild, as indicated by the data at Hankow and Chungking. The Kudo flora contains no evergreen and few warm temperate deciduous hardwoods, which are commonly included in the Mixed Mesophytic forest. The Mixed Northern Hardwood Forest is distributed northward from the Yangtze Valley, and contains many living trees similar to the Kudo plants. The climate of this region is less in precipitation and temperature than in the Yangtze region. For instance, at Kaifung and Siking there is a mean annual temperature of 12° to 13° C., an average winter temperature of 0.6° ~ 0.8° C. and a mean annual precipitation of 500-580 mm.. Compared with the Mixed Northern Hardwood forest of this region, the Kudo forest shows more abundance and more variety in the deciduous hardwood species. It is probable that the Kudo climate had a larger precipitation than in northern China.

The Yoshioka flora of southwestern Hokkaido which was investigated in detail by the author (Tanai, 1963), is composed mainly of deciduous hardwoods, with associated several warm temperate trees such as evergreen oak, *Liquidambar, Mahonia, Camellia* and others. The Yoshioka flora represents the Middle Miocene climate of the lower slopes and flood plain, which was mild, partly due to marine influence. However, the sites of the Kudo deposition appears to have been in interior basin at middle altitudes, and to have few maritime influence.

From the above discussion of climatic conditions under which the modern slope forest similar to the Kudo forest is growing in East Asia, it is concluded that the Kudo climate had a mean annual temperature from 10° to 12° C. and a mean annual precipitation 1200 to 1400 mm.. The Kudo flora contains no *Matasequoia,* which is commonly found through the Tertiary of Japan. The absence of *Metasequoia* may suggest that it was under low temperature during winter season of the Kudo time.

The Garo Flora

The Garo flora was first discovered by K. SAWAMURA and M. YOSHII in 1965 during their geological survey of the Kudo sheet map. The senior author visited the fossil locality with them in the autumn of 1966, because the age determination of the plant-bearing formation is urgently necessary for the Miocene stratigraphy of this region. The authors visited again there to have a further collection. This collection is not sufficient to consider the paleoecological condition of the flora, but may be enough to determine geological age.

Geographic and Geologic Setting

The fossil locality is situated about 5 km. north of the Kudo locality, and is on the north-central part of the Kudo sheet map. The locality extends along the cliffs in the middle course of the Garozawa, situated about 2 km. from the joining point of the Garozawa and the Futamata river.

Along the Garozawa the Futoro formation is widely distributed on the undulated basement of granitic rocks, and is composed principally of andesitic tuff, tuff breccia and agglomerate, partly with interbedded sandstone and siltstone. The plant fossils are found in tuffaceous, fine-grained sandstone, which is intercalated in the upper part of the Futoro formation. Most of the plant fossils are represented by leaves or leaflets, and also by seeds, nuts, cone scales and bracts. They are mostly impressions, and some of them have carbonized matters. The plant-bearing formation is covered unconformably by the Futorogoe siltstone member (the Sekinai formation) and by the marine Hidarimatagawa formation.

The surrounding area consists of low, hilly mountains with the elevations of 300-400 meters above the sea level. The forest of this area is quite similar to that of the Kudo area.

Composition of the Flora

The Garo flora comprises 27 species, representing 22 genera and 12 families. These plants comprise one fern, seven conifers and 18 dicotyledons: excluding one new species of *Picea,* all of these species have been already reported from the Miocene of southwestern Hokkaido. The largest family is the Pinaceae with three genera and six species, and the next is the Betulaceae with five genera and five species. The remaining families are represented by one or two genera. Most genera are represented by a single species except for *Abies* and *Picea* with three species each, and *Acer* with two. The Garo flora is characterized by having a variety of the Pinaceae which is mostly represented by the heavy organs such as cone or cone-scales. Most of dicotyledons are represented by fragmentary leaves or leaflets, excepting *Hemitrapa* and *Trapa,* and are largely ill-preserved. Following is the list of plants which make up the Garo flora.

Systematic List of Families and Species

Osmundaceae
- *Osmunda sachalinensis* KRYSHTOFOVICH

Pinaceae
- *Abies aburaensis* TANAI
- *Abies n-suzukii* TANAI
- *Picea garoensis* new species
- *Picea kaneharai* TANAI and ONOE
- *Picea ugoana* HUZIOKA
- *Tsuga miocenica* TANAI

Salicaceae
- *Populus nipponica* TANAI and N. SUZUKI
- *Salix miosinica* HU and CHANEY

Juglandaceae
- *Carya miocathayensis* HU and CHANEY
- *Juglans nipponica* TANAI
- *Pterocarya asymmetrosa* KONNO

Betulaceae
- *Alnus usyuensis* HUZIOKA

Betula uzenensis TANAI
Carpinus subcordata NATHORST
Corylus macquarrii (FORBES) HEER
Ostrya shiragiana HUZIOKA

Ulmaceae
Ulmus longifolia UNGER
Ulmus shiragica HUZIOKA

Cercidiphyllaceae
Cercidiphyllum crenatum (UNGER) BROWN

Aceraceae
Acer subpictum SAPORTA
Acer miodavidii HU and CHANEY

Tiliaceae
Tilia protojaponica ENDO

Hydrocaryaceae
Hemitrapa borealis(HEER) MIKI
Trapa ezoana TANAI and N. SUZUKI

Alangiaceae
Alangium aequalifolium (GOEPP.) KRYSHT. and BORSUK

Oleaceae
Fraxinus wakamatsuensis TANAI and N. SUZUKI

To the megafossil list may be added a microfossil list based on the current studies by S. SATO. From the plant-bearing fine-grained sandstone and lignite interbedded in somewhat upper horizon, a number of spores and pollen have been found, and their families and genera as follows:

List of Microfossils

Pinaceae*
indet. genera
*Tsuga**

Taxodiaceae

Myricaceae
Myrica

Salicaceae
*Salix**

Juglandaceae
*Carya**
*Juglans**
*Pterocarya**

Betulaceae
*Alnus**
*Betula**
*Carpinus**
*Corylus**

Fagaceae
Fagus
Quercus

Ulmaceae
*Ulmus** or *Zelkova*

Hamamelidaceae
Liquidambar

Tiliaceae
*Tilia**

Aceraceae
*Acer**

Of the above list, the genera and families with asterisk are represented also by megafossils. The microfossil record is generally similar to the megafossil flora in the generic composition, similar as in the case of the Kudo flora. However, it is noteworthy that the plants belonging to the Fagaceae and Hamamelidaceae are not recorded in the megaflora. Both mega- and microfloras are composed mainly of temperate families such as the Pinaceae, Salicaceae, Juglandaceae, Betulaceae, Ulmaceae and Aceraceae, all of which species account for nearly three-third of the total species. It is significant that in the megaflora missing are *Castanea, Quercus* (evergreen), *Comptonia,* Leguiminosae, Lauraceae and *Camellia,* which are in varying degree of regular occurrence in the Yoshioka, Wakamatsu and Abura floras of southwestern Hokkaido. *Liquidambar* is recorded only by pollen in the Garo microflora, though of rare occurrence.

The probable habitat of the Garo plants is determined, judging from their modern equivalent species: there are 22 different species of trees, two shrubs and three herbs. Tertiary pollen is hardly ever possible to determine its specific relationships with the modern plants. But we can added more than three trees and one shrub in the Garo forest, considering from the microfossil list.

A count was made of only 167 specimens of the megaflora from one locality, as shown in Table 5. This count is too small to preclude that certain species, especially the species represented by rare specimens, may have been more numerous in the Garo forest than is suggested by these figures. But it seems probable that the proportionate representation of the dominant members would not be greatly changed by a larger count. Of the 27 species recorded as megafossils, the first nine species in Table 5 are abundant, making up nearly 78 per cent of the total specimens. Especially the dominants are *Abies aburaensis, Tilia protojaponica, Osmunda sachalinensis* and *Abies n-suzukii;* these four species comprises about 60 per cent of the fossils collected. The abundance of two fir species is surprising, showing more than 30 per cent of the total, although the living equivalent species are now living in the subalpine forest of high altitudes in Honshu. On the one hand, nearly half of the species are very sparse in occurrence, and are represented by only one or two specimens.

The relative abundance of the microfossils is not always consistent with that of the megafossils, though the mega- and microfloras from the Garozawa locality are generally similar in their generic composition. The microfossil record from the plant-bearing rocks indicates that *Alnus* pollen is most abundant, and is followed by pollen of *Ulmus* or *Zelkova, Fagus, Carpinus* and the Pinaceae (excepting for *Tsuga* and *Larix*). It is noteworthy that pollen belonging to the Pinaceae is further less recorded than is expected from the

Table 5 Numerical Representation of Garo Species

Species	Number of Specimens	Percentage
Abies aburaensis (cone scale)	44	26.4
Tilia protojaponica	34	20.4
(leaves)	(32)	
(bracts)	(2)	
Osmunda sachalinensis	14	8.4
Abies n-suzukii (cone scales)	9	5.4
Juglans japonica	8	4.8
Ulmus shiragica	6	3.6
Tsuga miocenica	5	3.0
(cones)	(2)	
(cone scales)	(3)	
Populus nipponica	5	3.0
Corylus macquarrii	5	3.0
(leaves)	(4)	
(nut)	(1)	
Ostrya shiragiana	4	2.4
Ulmus longifolia	4	2.4
Pterocarya asymmetrosa	3	1.8
Cercidiphyllum crenatum	3	1.8
Acer subpictum (samaras)	3	1.8
Picea kaneharai (winged seeds)	2	1.2
Carya miocathayensis	2	1.2
Betula uzenensis	2	1.2
(leaf)	(1)	
(winged seed)	(1)	
Alnus usyuensis	2	1.2
Carpinus subcordata	2	1.2
(leaf)	(1)	
(nut)	(1)	
Acer miodavidii	2	1.2
Hemitrapa borealis (nuts)	2	1.2
Picea ugoana (winged seed)	1	
Picea garoensis (cone)	1	
Salix miosinica	1	3.6
Trapa ezoana (nut)	1	
Alangium aequalifolium	1	
Fraxinus wakamatsuensis	1	
Total specimens	167	99.8

Note: Unless otherwise stated, the organs recorded are leaves or leaflets.

abundant occurrence of the megafossils. It may be due partly to the fact that the plant-bearing rocks are made up of rather coarse materials such as sandstone.

The Garo flora is supposed to have been principally derived from a conifer-deciduous hardwood forest, which lived near the sites of deposition. Six of 22 trees are montane conifers, of which three species show high representation in fossil record. Most of dicotyledonous trees are represented by few specimens, except for *Juglans, Ulmus* and *Populus;* these three trees were confined mainly to stream- and lake-border sites.

Distributional Considerations

All of the Garo genera including those represented by pollen are distributed in East Asia, especially in China, and are typically north temperate in their present distribution with an exception of *Liquidambar.* These East Asiatic genera are still living in Japan, excluding *Carya* and *Liquidambar,* and most of them are also distributed in eastern North America excepting for *Pterocarya, Cercidiphyllum* and *Alangium.* Table 6 gives a list of the Garo species with their living equivalents and modern distribution in East Asia and North America. In some case second similar living species are included in parenthesis. From this list are omitted three herbaceous plants such as *Osmunda, Trapa* and *Hemitrapa.*

Considering the distribution of the living equivalent species shown in Table 6, it is readily apparent that they are concentrated in two regions of East Asia: in Japan from northern to central Honshu, and in China from the northern to the central. The abundance of montane conifers in fossil record turns our attention first to the conifer-deciduous hardwood forest in these regions.

Related Modern Forests

In central and northern Honshu, vegetation above the beech zone forest is a mixed forest of conifers and deciduous broad-leaved trees: it occurs from altitudes of 1500-1800 meters up to 2200-2600 meters in central Honshu, and from 1000-1400 meters up to 1700-2200 meters in northern Honshu. For instance, this mixed forest is typically developed on higher slopes of Mt. Ontake, Mt. Hotaka and the Chichibu mountains in central Honshu, and of Mt. Hakkoda, Mt. Zao and Mt. Hayachine in northern Honshu.

In the mixed forest of these mountains are observed many trees which are closely related, or generally similar to the Garo species. There is a marked difference between them, though the Garo flora closely resembles the modern mixed forest as shown in Table 7. The Garo flora contains few plants similar to the subalpine broad-leaved trees such as *Alnus maximowiczii, Betula ermani,*

Table 6 The Modern Equivalents of the Garo plants and their Distribution in East Asia and North America.

Fossil species	Modern Equivalents	East Asia													North Amer.	
		Japan						China								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Abies aburaensis	*A. homolepis*				X	X	X									
Abies n-suzukii	*A. mariesii*			X	X											
Picea garoensis	*P. maximowiczii*				X											
Picea kaneharai	*P. neoveitchii (polita)*				(X)	(X)	(X)			X			X			
Picea ugoana	*P. bicolor*				X											
Tsuga miocenica	*T. longibracteata*											X				
Populus nipponica	*P. heterophylla*															X
Salix miosinica	*S. wilsonii*										X	X	X			
Carya miocathayensis	*C. cathayensis*										X	X				
Juglans nipponica	*J. ailanthifolia*	X	X	X	X	X	X									
Pterocarya asymmetrosa	*P. rhoifolia*		X	X	X	X	X			X						
Alnus usyuensis	*A. sitchensis*														X	
Betula uzenensis	*B. schmidti*		X	X	X				X					X		
Carpinus subcordata	*C. cordata*		X	X	X	X	X		X	X	X			X		
Corylus macquarrii	*C. heterophylla*		X	X	X	X	X									
Ostrya shiragiana	*Q. japonica (virginiana)*		X	X	X	X	X		X	X	X					(X)
Ulmus longifolia	*U. lanceofolia*											X				
Ulmus shiragica	*U. davidiana*		(X)	(X)	(X)	(X)	(X)		X	X				X		
Cercidiphyllum crenatum	*C. japonicum*		X	X	X	X	X			X	X	X				
Acer subpictum	*A. mono*	X	X	X	X	X	X		X	X	X	X		X		
Acer miodavidii	*A. davidii*									X	X	X	X			
Tilia protojaponica	*T. japonica*		X	X	X	X	X				X					
Alangium aequalifolium	*A. platanifolium*		X	X	X	X	X									
Fraxinus wakamatsuensis	*F. lanceolata*															X
Nuber of Nearest species		2	10	11	14	10	10	0	5	8	8	7	3	4	1	2

1. Saghalien, Kurile Islands.
2. Hokkaido.
3. Northern Honshu.
4. Central Honshu.
5. Southern Honshu.
6. Kyushu and Shikoku.
7. Formosa and Loochoo Islands.
8. Korea.
9. North China.
10. Central China.
11. Southwest China.
12. Southeast China.
13. Manchuria.
14. Western North America.
15. Eastern North America.

Sorbus matsumurana and others, which are common members in the mixed forest. Most of the broad-leaved trees listed in this table extend down into the upper beech zone forest, and are growing rather luxuriantly there. Actually, all of the deciduous hardwood trees of the Japanese Component shown in Table 7, are found in the beech zone forest of Honshu. But, with an exception of *Tilia protojaponica*, no dominant species of the hardwood trees are recorded in the Garo flora. Furthermore, it is also noteworthy that the remains of *Fagus* characterizing the beech zone forest is represented only by pollen in the fossil record.

Table 7 Modern Equivalents in the Conifer-deciduous Hardwood Forest of Northern and central Honshu

Garo flora	Central Honshu	Northern Honshu
Abies aburaensis	*A. homolepis*	**A. veitchii*
Abies n-suzukii	*A. mariesii*	*A. mariesii*
Picea kaneharai	*P. polita*	*P. polita*
Picea garoensis	*P. maximowiczii*	
Picea ugoana	*P. bicolor*	
Tsuga miocenica	**T. diversifolia*	**T. diversifolia*
Populus nipponica	**P. maximowiczii*	**P. maximowiczii*
Salix miosinica		**S. sachalinensis*
Pterocarya asymmetrosa	*P. rhoifolia*	*P. rhoifolia*
Alnus usyuensis	**A. hirsuta*	**A. hirsuta*
Quercus-pollen	*Q. mongolica* var.	*Q. mongolica* var.
Fagus-pollen	*F. crenata*	*F. crenata*
Ulmus shiragica	**U. davidiana*	**U. davidiana* var.
Cercidiphyllum crenatum	*C. japonicum*	*C. japonicum*
Acer subpictum	*A. mono*	*A. mono*
Tilia protojaponica	*T. japonica*	*T. japonica*
Fraxinus wakamatsuensis	**F. sieboldiana* var.	**F. sieboldiana* var.

*More distantly related species

Relationships with Chinese Modern Forest

The typical members of the Chinese Component are less represented than those of the Japanese Component, compared with the Kudo flora described in the preceding chapter. Adding somewhat distantly similar species to this consideration, there are a somewhat greater resemblance between the Garo flora and the upland forest of western Hupeh and Szechuan, as follows:

Garo flora	Upland forest of central China
Abies aburaensis; A. n-suzukii	*Abies* spp.

Picea kaneharai	*P. neoveitchii*
Picea ugoana	*P. asperta*
Tsuga miocenica	*T. longibracteata*
Populus reniformis	*P. adenopoda*
Salix miosinica	*S. wilsonii*
Pterocarya asymmetrosa	*P. hupehensis*
Carya miocathayensis	*C. cathayensis*
Betula uzenensis	*B. luminifera*
Carpinus subcordata	*C. cordata*
Corylus macquarrii	*C. chinensis*
Ostrya shiragiana	*O. japonica*
Fagus-pollen	*F. longipetiolata*
Ulmus shiragica	*U. davidiana*
Cercidiphyllum crenatum	*C. japonicum* var.
Liquidambar-pollen	*L. formosana*
Acer subpictum	*A. mono*
Acer miodavidii	*A. davidii*
Tilia protojaponica	*T. oliveri*
Fraxinus wakamatsuensis	*F. chinensis* var.

In these regions the Mixed Mesophytic Forest is luxuriantly growing at middle altitudes. The typical members of this forest are uncommon in frequency of specimens in the Garo flora, similar as in the case of comparison with the Japanese Component. Especially it is noteworthy that *Metasequoia* is not included in the Garo flora.

From comparison with the modern related forests in East Asia, it may be concluded that the Garo flora find a close similarity to the ecotone between the mixed deciduous hardwood and montane conifer forests, which is situated at somewhat higher altitudes.

The Garo Plant Communities

Combining the evidence derived from the distribution of its modern similar species in East Asia, and the relative abundance of its members, the Garo flora may be subdivided into four communities.

Aquatic Vegetation

Only two aquatic herbs, *Hemitrapa* and *Trapa,* belong to this community, and they appear to have lived in a small, local lake. These two species represented only by nuts show sparse frequency in fossil record, and they were probably uncommon members in the Garo basin.

Lake- and Stream-border Community

This community is composed of the following 11 species, most of which are mesic to near-hydric plants.

Alangium aequalifolium
Carya miocathayensis
Corylus macquarrii
Juglans japonica
Osmunda sachalinensis
Ostrya shiragiana
Populus reniformis
Pterocarya asymmetrosa
Tilia protojaponica
Ulmus shiragica
Ulmus longifolia

The predominance of *Tilia* (20 per cent) shows that linden trees lived luxuriantly in the lake margins and stream boaders close to the area of plant accumulation. Judging from the fossil occurrence and the habitat of their modern equivalents, *Juglans, Ulmus* and *Corylus* were probably common members in this community. *Osmunda* appears to have been a common herb in the understory of this forest. *Liquidambar* represented only by pollen may be included in the uncommon member of this community.

Conifer-Deciduous Hardwood Forest

More than half species of the total Garo plants are included in this community, and they lived on valley flats and lower slopes bordering the lake. They are the following 14 plants, though some trees extended up into this community from the lake borders.

Abies aburaensis
Abies n-suzukii
Picea kaneharai
Tsuga miocenica
Acer miodavidii
Acer subpictum
Alnus usyuensis
Betula uzenensis
Cercidiphyllum crenatum
Fraxinus wakamatsuensis
Pterocarya asymmetrosa
Salix miosinica
Tilia protojaponica
Ulmus shiragica

To this list, we may add *Fagus* and *Quercus* as the uncommon members, because these two are represented only by pollen in the Garo flora. Of the trees listed above, *Abies n-suzukii* appears to have grown dominantly at higher altitudes than this community, as judged from the present altitudinal distribution of its living equivalent species.

Montane Conifer Forest

This community composed predominantly of montane conifers probably occupied bordering hills, and some of these conifers extended down into the above-noted mixed forest on northerly slopes and valleys. The members of this community are as follows:

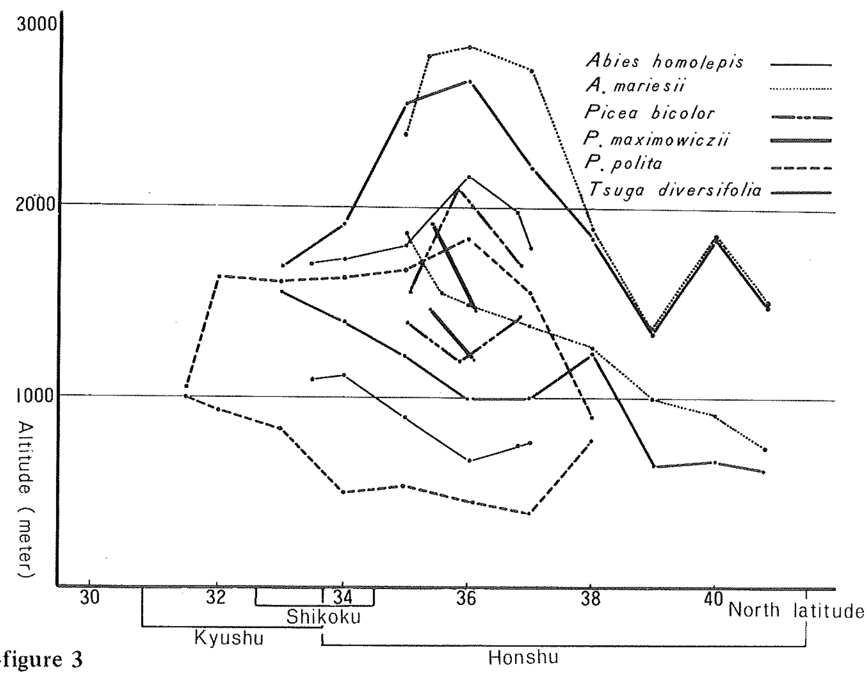
Abies aburaensis
Abies n-suzukii
Picea garoensis
Picea kaneharai
Picea ugoana
Tsuga miocenica

Tilia protojaponica

Of these trees, most of conifers are relatively well represented by heavy materials such as cone and cone scales. *Picea ugoana* represented by only one winged seed, was probably uncommon member in this community.

Summary

The analysis of modern distribution and habitat of the Garo equivalent species in East Asia, and of quantative significance of the fossil record, reached a conclusion that the Garo flora is composed of plant structures contributed by a conifer-deciduous hardwood forest to tuffacaous sediments that accumulated in a small upland lake. The plant-bearing Futoro formation was deposited with thick pyroclastic rocks in the basin, which was made up of unevened granitic rock basement of Pre-Tertiary time. As already described, most of the montane conifers are abundantly contained in the Garo flora; total of conifers show high scores (more than 37 per cent) in fossil counting. The modern equivalent species of these conifers are distributed at middle to high altitudes in Honshu, as shown in Text-figure 3. Considering the abundance of two firs and altitudinal distribution of six conifers, it is supposed that the sites of Garo deposition were probably at high elevation, at least of 800 to 1000 meters above the sea level.



Text-figure 3
Altitudinal Distribution of the Modern Conifers related to the Garo Species (data from I. Hayashi, 1960).

Climatic Conditions

The Garo flora find a close similarity to the ecotone between the mixed deciduous hardwood and the montane conifer forests, and is considered to have lived at somewhat higher altitudes. These modern similar forests are distributed on upper slopes and uplands of central and northern Honshu.

No reliable climatic records are not available directly for upper slopes and montane regions of central Honshu. Karuizawa at an altitudes of 934 meters has a mean annual temperature of 7.7° C., winter monthly average temperature of −8.6°C., and a mean annual precipitation of 1364 mm. In the montane region of central Honshu, climate is somewhat lower in the mean annual temperature, and is higher in annual precipitation than at Karuizawa. Many similar plants of the Kudo species are also found in the mixed conifer-hardwood forest of northeastern Honshu, for instance, on upper slopes of Mt. Hakkoda. In Morioka, at lower altitudes, the climatic data show a mean annual temperature of 9.3°C., winter monthly average temperature −6.7°C., and a mean annual precipitation of 1205 mm. The precipitation in this region increases toward higher altitudes.

The abundance of many conifers in the Garo flora whose nearest analogues now occur in areas with snow during winter season, may suggest that it was probably somewhat snowy near the sites of deposition in winter. Thus the Garo climatic conditions at higher altitudes were probably worse than those indicated by the Yoshioka and the Kudo floras; there were a mean annual temperature of 8°~9°C., with winter temperature falling frequently below freezing, and mean annual precipitation of more than 1300 mm.

The Wakamatsu Flora

The Middle Miocene Wakamatsu flora was already described in detail by the authors (TANAI and N. SUZUKI, 1963) on the basis of a collection from the Wakamatsu coal mine. This flora lies between the Kudo flora at the south and the Garo flora at the north. Plant fossils were discovered from the coal-bearing Sekinai formation at other three localities by Dr. K. SAWAMURA and Mr. HATA of the Geological Survey of Japan. The senior author visited these localites with them in 1966, and collected a number of well-preserved plants. The florules from these three localities are closely similar to the flora already described, but several species were newly found. As these localities are included stratigraphically in the same formation, the authors call all of these four the Wakamatsu flora.

Though adding new data, the flora now redesignated is not nearly different from the previously reported flora in floral composition and relative abundance of dominant members. Accordingly, it seems unnecessary to discuss again on paleoecology. The authors will describe here only the fossil list and their occurrence from new localities.

Geologic Occurrence

Westward from the national road 229, the Futorogoe-zawa siltstone member is distributed intermittently on the Futoro formation from Miyano to Garozawa. This member contains sometimes thin lignite seams once worked at the Wakamatsu coal mine, and includes a number of well-preserved plant fossils. The plant-bearing rocks are tuffaceous, well-laminated siltstone, and plant fossils are represented mostly by leaf and winged seed impressions. They were recently collected from three localities as shown Text-fig. 2: the abandoned open-cut mine west of Kanagasawa village (Kanagasawa loc. 2); the cliff at the upper course of the Futorogoe-zawa (Miyano loc. 2) and the cliff at its lower course (Miyano loc. 1), both northeast of Miyano village.

This plant-bearing member was treated as the basal part of the Kunnui formation in the previous report, but was recently designated as a member of the Sekinai formation which is contemporaneous with the Yoshioka formation by HATA *et al.* (1971). This member is covered unconformably by the marine sandstone member of the Hidarimatazawa formation.

Composition of the Flora

The flora previously reported was composed of 36 species, found from the Wakamatsu coal mine (Kanagasawa loc. 1). Most of these species are found also at three new localities, and ten species are added to the previous floral list. The Wakamatsu flora now redesignated is distributed in 20 families, 33 genera and 46 species. All of these species with a few exception have been known from the Miocene of southwestern Hokkaido. The largest family is the Pinaceae with six genera and eight species, next are the Betulaceae and Aceraceae with seven species each, and the Juglandaceae with three genera and four species. The remaing families are represented by one or two species, excepting the Fagaceae with three species. The plants determined from four localities are shown in the following Table 8.

The previous quantative appraisal of the Wakamatsu flora was based on a count of 366 specimens from one locality (Kanagasawa loc. 1). The further collection made up of 526 specimens from other three localities is added to the previous counting, and the relative abundance of species are recalculated as shown in Table 9. The rare members represented by less than 4 specimens are excluded from this table. Of the 46 species identified, the five dominant members are *Castanea miomollissima, Zelkova ungeri, Quercus miovariabilis, Fagus antipofi* and *Carpinus subcordata*, and they make up more than 80 per

Table 8 Systematic List of the Wakamatsu Flora

	Fossil species	1	2	3	4
Pinaceae	*Abies aburaensis* TANAI	X	...	...	...
	Keteleeria ezoana TANAI	X	...	X	X
	Picea kaneharai TANAI et ONOE	X	X	...	X
	Picea kanoi HUZIOKA	X	X	...	...
	Picea ugoana HUZIOKA	X	...	...	...
	Pinus miocenica TANAI	X	...	...	...
	Pseudotsuga ezoana TANAI	X	...	...	X
	Tsuga miocenica TANAI	X	X	...	X
Taxodiaceae	*Metasequoia occidentalis* (NEWB.) CHANEY	X	X	X	X
Cupressaceae	*Thuja nipponica* TANAI et ONOE	X	...	...	...
Salicaceae	*Populus nipponica* TANAI et N. SUZUKI	X	...	...	...
Myricaceae	*Comptonia naumanni* (NATH.) HUZIOKA	X	...	...	...
Juglandaceae	*Carya miocathayensis* HU et CHANEY	X	...	...	...
	Juglans shanwangensis HU et CHANEY	X	...	...	...
	Pterocarya ezoana TANAI et N. SUZUKI	X	...	...	...
	Pterocarya protostenoptera TANAI	...	X	...	...
Betulaceae	*Alnus miojaponica* TANAI	X	...	...	...
	Alnus protomaximowiczii TANAI	X	X	X	X
	Carpinus miofangiana HU et CHANEY	X	...	...	X
	Carpinus mioturczaninovii HU et CHANEY	...	X	X	X
	Carpinus subcordata NATHORST	X	X	X	X
	Carpinus subyedoensis KONNO	X	...	X	...
	Ostrya shiragiana HUZIOKA	...	X	...	...
Fagaceae	*Castanea miomollissima* HU et CHANEY	X	X	X	X
	Fagus antipofi HEER	X	X	X	X
	Quercus miovariabilis HU et CHANEY	...	X	X	X
Ulmaceae	*Ulmus longifolia* UNGER	X	X	...	...
	Zelkova ungeri KOVATS	X	X	X	X
Eucommiaceae	*Eucommia japonica* TANAI	...	X	...	...
Magnoliaceae	*Magnolia miocenica* HU et CHANEY	X	...	...	...
Leguminosae	*Cercis miochinensis* HU et CHANEY	...	...	X	X
	Ribinia nipponica TANAI	X	...	...	...
Rutaceae	*Phellodendron mioamurense* TANAI	...	X	...	...
Anacardiaceae	*Rhus miosuccedanea* HU et CHANEY	X	...	...	...
Aceraceae	*Acer ezoanum* OISHI et HUZIOKA	X	X	...	...
	Acer miohenryi HU et CHANEY	X	X	X	X
	Acer protodistylum ENDO	...	X	...	...
	Acer protojaponicum TANAI et ONOE	X	...	...	...
	Acer prototataricum TANAI et N. SUZUKI	...	X	...	...
	Acer pseudoginnala TANAI et ONOE	X	X	...	X
	Acer subpictum SAPORTA	X	...	...	X
Tiliaceae	*Tilia protojaponica* ENDO	X	...	...	...
Theaceae	*Camellia protojaponica* HUZIOKA	X	...	...	...
Hydrocaryaceae	*Hemitrapa borealis* (HEER) MIKI	X	...	...	...

Alangiaceae	*Alangium aequalifolium* (GOEP.) KRYSHT et BOR.	···	···	···	X
Oleaceae	*Fraxinus wakamatsuensis* TANAI et N. SUZUKI	X	···	···	···
	Number of species	46	21	12	18

Localities: 1. Kanagasawa loc. 1
2. Kanagasawa loc. 2
3. Miyano loc. 1
4. Miyano loc. 2

Table 9 Numerical Representation of the Wakamatsu Species

	Kanagasawa		Miyano		Total	Per-cent
	1	2	1	2		
Castanea miomollissima	195	45	22	187	449	50.3
Zelkova ungeri	20	42	33	23	118	13.2
Quercus miovariabilis	···	23	12	18	53	5.9
Fagus antipofi	32	5	1	7	45	5.0
Carpinus subcordata	12	6	7	8	33	3.7
Picea kaneharai (winged seeds)	14	4	···	4	22	2.5
Acer ezoanum	11	5	···	···	16	1.8
(leaves)	(8)	(4)	···	···	···	···
(samara)	(3)	(1)	···	···	···	···
Carpinus miofangiana	14	···	···	1	15	1.7
Acer miohenryi	4	4	1	5	14	1.6
Alnus protomaximowiczii	6	2	2	3	13	1.5
Metasequoia occidentalis	2	3	5	1	11	1.2
(foliaged shoots)	(2)	(3)	(5)	···	···	···
(cone)	···	···	···	(1)	···	···
Carpinus mioturczaniovii	···	2	4	5	11	1.2
(leaves)	···	···	(2)	(2)	···	···
(bracts)	···	(2)	(2)	(3)	···	···
Acer subpictum	2	···	···	7	9	1.0
Pinus miocenica	7	···	···	···	7	0.8
Acer pseudoginnala (samaras)	3	2	···	2	7	0.8
Carpinus subyedoensis	2	···	4	···	6	0.7
Abies aburaensis	5	···	···	···	5	0.6
Keteleeria ezoana (winged seeds)	3	···	1	1	5	0.6
Picea kanoi (winged seeds)	4	1	···	···	5	0.6
All others, 4 or fewer specimens each	30	8	2	8	48	5.3
Totals					892	100.0

Note: Unless otherwise stated, the organs recorded are leaves or leaflets.

cent of the total 892 specimens. The abundance of these species indicates that the Wakamatsu flora is closely related to the modern "*Castanea* zone forest" of

Japan, considering the habitat and the distribution of their living equivalents.

The Wakamatsu flora is composed mainly of temperate trees belonging to the Pinaceae, Juglandaceae, Betulaceae, Fagaceae, Ulmaceae and Aceraceae. As already discussed in the previous report, the Wakamatsu flora shows an intermediate relationship to the lowland and slope forests of the Yoshioka flora, and to the slope and upland forests of the Abura. These differences, involving the representation of the dominant species, appear to have been due to topographic than climatic factors. The Wakamatsu flora contains abundantly *Zelkova* and *Castanea* which are predominant in the Yoshioka and rare in the Abura, and *Fagus* which is predominant in the Abura and represented only by pollen in the Yoshioka. The previous conclusion that steep slopes may have been present on the borders of the Wakamatsu basin, is consistent with paleogeographic setting: west of this area there were probably the upland composed of Pre-Tertiary sediments and granodiorite.

Age Discussion

Stratigraphic Evidence

The recent advancement of Miocene geology in this region has revealed the stratigraphic position of the plant-bearing sediments. The Garo flora is preserved in tuffaceous sandstone of the upper part of the Futoro formation, which is the lowest member of the Tertiary section. This formation is correlated with the Lower Miocene Fukuyama formation, because of the similar lithology which is represented mainly by altered pyroclastic rocks. On the one hand, the Wakamatsu flora is contained in the Futorogoe-zawa member, which covers the Futoro formation with an unconformity. This member is composed mainly of tuffaceous siltstone with a few thin lignite seams, and is correlated in lithology with the Yoshioka formation including the Middle Miocene Yoshioka flora. It is unconformably overlain by the Hidarimatagawa formation composed of thick marine sediments. Thus the Miocene sequence of this region corresponds well with the typical sequence of the Matsumae-Fukushima region, where a standard section of the Miocene is observed in southwestern Hokkaido. Accordingly, the stratigraphic evidence apparently indicates that the Garo flora is older than the Wakamatsu flora, and may be Early Miocene in age.

The Kudo flora is found from the siltstone intercalations in the basaltic lava member, which covered the Futoro formation. The Futorogoe-zawa member is not developed in the Kudo-Miyano area, and is considered to be correlated with the basalt lava member. This basalt lava member is somewhat altered, and was previously included in the Futoro formation. However, the recent paleobotanical evidence, as described later, shows to be younger than the Futoro.

Paleobotanical Evidence

The Miocene floras of Japan have been investigated in detail by many authors, and the general aspect of these forests was revealed in latitudinal distribution. The Early Miocene flora designated as the Aniai-type, is composed mainly of cool-temperate hardwoods and conifers, while the Middle Miocene flora designated as the Daijima-type, consists of temperate hardwoods, associating with a number of warm-temperate evergreen broad-leaved trees and conifers. In the previous report the authors revealed that the Middle Miocene flora of southwestern Hokkaido has less evergreen broad-leaved trees than that of Honshu. Thus, the altitudinal and latitudinal distribution of Middle Miocene forests in Japan were discussed with showing schematic figures by the author (TANAI, 1967).

A method frequently used in age analysis is grouping species in a table to show their distribution in other floras of known age. This procedure may involve some questions for accurracy if the altitudinal and latitudinal distribution of forests was not taken account. It has been accentuated that the problem of altitudes as well as latitudes is an important factor for age evaluation of the fossil flora. The procedure shown in Table 10 seems useful for age analysis, because it is employed within restricted area such as from northern Honshu to southwestern Hokkaido. The floras used for comparison are great in size, and were fully investigated on their paleoecology: they are the Ani, the Kaminokuni and the Sakipenpetsu floras of Early Miocene age, and the Utto, the Yoshioka and the Abura floras of Middle Miocene age.

As shown in Table 10, the Garo flora shows the higher number of species in common with Early Miocene floras such as the Utto and the Kaminokuni floras. It is naturally accepted that the Garo flora has many species common with the Abura flora which represents an upland forest of the Middle Miocene. This similarity of floristic composition is due not to the age, but to the upland character. On the one hand, the Kudo flora has the higher number of species in common with Middle Miocene floras such as the Yoshioka and the Abura floras. It is noteworthy that the Kudo flora has lesser species with the Middle Miocene Utto flora, and on the contrary has more species with the Lower Miocene Kaminokuni flora. This fact indicates that Middle Miocene vegetation of Japan was with a distinct latitudinal distribution as already discussed by the senior author (Tanai, 1967), and that the Kudo flora represents a slope forest at somewhat high altitudes.

In the column of the age shown in Table 10, we find that the Garo flora shows its closer relation to those of Early Miocene age with 24 species in common, as compared to Middle Miocene floras with 22 species in common. Similar comparison with the Kudo flora shows that it has 25 species in common with Middle Miocene floras, and 21 species in common with Early Miocene floras. These comparison may indicate the age of the Garo and Kudo floras, though the number of common species are not so greater than is expected as the age difference. Such vagueness of age evaluation is due mainly to the facts that Early and Middle Miocene floras of southwestern Hokkaido show generally a temperate aspect, and that these floras involve the forests distributed from the lowlands to the uplands, The Wakamatsu flora representing mainly the lower slope forest, shows its closest relationships to Middle Miocene floras with 41 species in common, as compared to Early Miocene floras with 30 common species, and is dated as Middle Miocene age as previously evaluated.

Combining the evidence derived from the stratigraphic relationships of plant-bearing rocks and the paleofloristic consideration, we can reach a conclusion on age of the floras: the Garo flora represents an upland vegetation of Early Miocene age, and the Kudo and the Wakamatsu floras are Middle Miocene in age.

Systematic Descriptions

Family Equisetaceae

Equisetum arcticum HEER

Equisetum arcticum HEER, K. svensk. vet. akad. ofvers. Förh. vol. 23, no. 6, p. 150, 1866.

TANAI, Jour. Fac. Sci. Hokkaido Univ., Ser. 4, vol. 14, no. 4, p. 455, pl. 3, figs. 1, 2, 1970.

Equisetum sp. TANAI and N. SUZUKI, Tert. Flora of Japan, p. 91, pl. 1, fig. 1, 1963.

Remarks: Four fragmentary stems are referred to *Equisetum arcticum*. This species is similar to the modern *E. hyemale* LINN. widely distributed in the Northern Hemisphere. *Equisetum* sp. from the Kaminokuni flora of southwestern Hokkaido (TANAI and N. SUZUKI, 1963) is included in *E. arcticum*.

Occurrence: Ogawa.

Family Osmumdaceae

Osmunda sachalinensis KRYSHTOFOVICH

Pl. 1, figs. 1, 2

Osmunda sachalinensis KRYSHTOFOVICH, Materials for Tertiary Lower Due flora of Saghalien, p. 708, pl. 1, figs. 4-6, text-figs. 1, 2, 1936.

TANAI, Jour. Fac. Sci. Hokkaido Univ., Ser. 4, vol. 14, no. 4, p. 456, pl. 3, figs. 5-7 (see synonymy and discussion), 1970.

Remarks: The specimens represented by 14 detached pinnules, are identical with *Osmunda sachalinensis* in their shape and venation characters. This species is closely similar to pinnules of the modern *O. japonica* THUNB. widely distributed in East Asia and Himalaya region. The fossil sterile pinna and pinnules were described from the Paleogene floras of the Ishikari and the Kushiro coal fields in Hokkaido. *O. tsunemoriensis* MATSUO from a Middle Miocene flora of north-central Honshu (MATSUO, 1953) is unseparable from species, and is probably conspecific.

Occurrence: Garozawa.

Collection: H.U.M.P., hypotypes nos. 26061, 26062.

Family Pinaceae

Abies aburaensis TANAI

Pl. 1, figs. 3-5

Abies aburaensis TANAI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, no. 2, p. 247, pl. 1, figs. 8, 9, 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 98, pl. 2, figs. 4, 8-11, 15, 33, 34, 1963.

Supplementary description: Cone scale, fanlike in general outlin, 3 cm. to 2.7 cm. wide and 2 cm. to 2.5 cm. high; broad and rectangular in middle to lower part; base cuneate, upper margin truncate or broadly rounded and overhunging at both side; longitudinal striae very clear.

Remarks: A number of cone scales are referred to *Abies aburaensis* by their characteristic shape. Seed and cone scales were described from the Abura, Wakamatsu and Kaminokuni floras in southwestern Hokkaido and Aniai type floras in Honshu. This species is closely similar to the modern *A. homolepis* SIEB. and ZUCC. (Pl. 1, figs. 6, 7) in central Honshu and Shikoku, which is growing at the altitudes of 1000 to 2000 meters in the conifer-decidous hardwood forest.

Occurrence: Garozawa and Kanagasawa loc. 1.

Collection: H.U.M.P., hypotypes nos. 26063-26065.

Abies n-suzukii TANAI

pl. 1, figs. 10-13

Abies n-suzukii TANAI, Jour. Fac. Sci. Hokkaido Univ., Ser. 4, vol. 11, p. 249, pl. 1, figs. 11, 13, 14; pl. 32, fig. 1, 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 98, pl. 1, figs. 12, 16; pl.

Table 10 Occurrence of Garo, Kudo and Wakamatsu Floras in other Miocene Floras of Northern Japan

Floras / Species	Garo	Kudo	Wakamatsu	Lower Miocene			Middle Miocene		
				Ani	Kaminokuni	Sakipenpetsu	Utto	Yoshioka	Abura
Equisetum arcticum	...	X	...	O	X	...	...	...	...
Osmunda sachalinensis	X	...	...	...	...	...	...	...	...
Abies aburaensis	X	...	X	X	...	...	...	...	X
Abies n-suzukii	X	...	...	...	X	...	...	X	X
Keteleeria ezoana	...	X	X	...	...	...	...	X	...
Picea garoensis	X	...	...	...	...	...	...	...	...
Picea kaneharai	X	X	X	X	X	...	X	X	X
Picea kanoi	...	...	X	X	...	...	...	...	X
Picea ugoana	X	X	X	X	X	...	...	X	X
Pinus miocenica	...	X	X	O	...	...	X	X	X
Pseudotsuga ezoana	...	...	X	O	...	...	X	...	...
Tsuga miocenica	X	...	X	X	X	...	...	X	X
Glyptostrobus europaeus	...	X	...	X	X	X	X	X	X
Metasequoia occidentalis	...	...	X	X	...	X	X	X	X
Thuja nipponica	...	...	X	X	...	...	...	...	X
Populus nipponica	X	...	X	...	...	O	...	O	...
Salix miosinica	X	...	...	X	X	...	...	X	...
Comptonia naumanni	...	X	X	...	...	X	X	X	X
Carya miocathayensis	X	...	X	X	X	...	...	X	X
Juglans japonica	X	...	...	X	...	...	X	...	...
Juglans shanwangensis	...	...	X	X	...	...	...	X	...
Pterocarya asymmetrosa	X	X	...	X	X	X	X	...	...
Pterocarya ezoana	...	...	X	...	...	X	...	X	X
Pterocarya protostenoptera	...	X	X	...	...	...	...	...	...
Alnus miojaponica	...	...	X	X	X	X	X	X	X
Alnus protomaximowiczii	...	X	X	...	...	X	X	X	X
Alnus usyuensis	X	...	...	X	X	...	...	...	...
Betula uzenensis	X	...	...	X	X	X	X	O	O
Carpinus miocenica	...	X	...	...	...	...	...	...	...
Carpinus miofangiana	...	...	X	...	X	...	...	X	X
Carpinus mioturczaninovii	...	...	X	...	...	...	...	X	...
Carpinus subcordata	X	X	X	X	X	X	X	X	X
Carpinus subyedoensis	...	X	X	X	X	...	X	X	X
Corylus macquarrii	X	X	...	O	X	...	...	X	X
Ostrya shiragiana	X	...	X	X	X	...	...	...	X
Castanea miomollissima	...	...	X	X	...	...	X	X	X
Fagus antipofi	...	X	X	X	X	...	X	...	X
Quercus miovariabilis	...	...	X	...	...	...	...	...	...
Ulmus carpinoides	...	X	...	...	...	...	...	...	...
Ulmus longifolia	X	...	X	...	X	O	X	X	X
Ulmus shiragica	X	...	...	X	X	O	...	...	X

Zelkova ungeri		···	X	X	X	X	X	X	X	X
Eucommia japonica		···	X	X	···	···	···	···	···	···
Cercidiphyllum crenatum		X	X	···	X	X	X	···	X	X
Magnolia miocenica		···	···	X	X	···	···	···	X	X
Cercis miochinensis		···	···	X	···	···	···	···	X	···
Gleditsia miosinensis		···	X	···	···	···	···	X	X	···
Pueraria miothunbergiana		···	X	···	···	···	···	···	···	···
Robinia nipponica		···	···	X	···	···	···	···	···	X
Phellodendron mioamurense		···	···	X	···	X	X	···	···	···
Rhus miosuccedanea		···	X	X	···	···	···	X	X	···
Acer ezoanum		···	X	X	X	X	X	···	X	X
Acer miodavidii		X	···	···	X	···	···	X	X	···
Acer miohenryi		···	X	X	X	X	···	···	X	X
Acer palaeodiabolicum		···	X	···	···	···	···	···	X	X
Acer protodistylum		···	···	X	X	···	···	···	X	···
Acer protojaponicum		···	X	X	···	X	···	···	X	X
Acer prototataricum		···	···	X	···	···	···	···	X	X
Acer pseudoginnala		···	···	X	X	···	···	···	X	···
Acer subpictum		X	X	X	X	X	X	X	X	X
Acer yoshiokaense		···	X	···	X	···	···	···	X	···
Tilia protojaponica		X	X	X	···	X	···	···	···	X
Camellia protojaponica		···	···	X	···	···	···	X	X	···
Hemitrapa borealis		X	X	X	X	O	O	···	X	···
Trapa ezoana		X	···	···	···	X	···	···	···	···
Alangium aequalifolium		X	···	X	X	···	···	X	···	···
Fraxinus wakamatsuensis		X	X	X	···	O	X	···	···	X
Carpolithes japonica		···	X	···	···	···	···	···	···	···
Garo	identical				18	18	6	12	13	15
	closely similar				1	2	4	0	2	1
Kudo	identical				14	16	10	13	21	19
	closely similar				3	2	1	0	0	0
Wakamatsu	identical				24	17	11	17	31	30
	closely similar				2	2	3	0	1	0
Garo identical		27				24			22	
Kudo identical			32			21			25	
Wakamatsu identical				46		30			41	

(X: identical species; O: closely similar species)

2, figs. 3, 12, 1963.

Supplementary description: Cone scales ellipsoidal in general outline, 2 cm. to 2.5 cm. wide, 1.5 cm. to 3 cm. (estimated) high; base cuneate; upper part of margin broadly rounded and basal part also rounded.

Remarks: A single seed and eight well-preserved cone scales are referred to *Abies n-suzukii.* Cone scales from Garozawa locality are characterized by ellipsoidal shape like mushroom, and are more well-preserved than the type-specimens. This species is closely similar to the modern *Abies mariesii* MAST. of northern and central Honshu, which is associated with *A. veitchi, Picea jezoensis* var. *hondoensis* and *Tsuga diversifolia* in montane forest.

Occurrence: Garozawa; H.U.M.P., hypotypes nos. 26066-26069.

Keteleeria ezoana TANAI

Pl. 1, figs. 9, 16

Keteleeria ezoana TANAI, Jour. Fac. Sci. Hokkaido Univ. Ser. 4, vol. 11, p. 251, pl. 1, figs. 16, 40, 41, 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 99, pl. 1, figs. 2-4; pl. 2, figs. 1, 2, 31, 1965.

Supplementary description: Staminate cone 2.4 cm. long, 0.7 cm. wide, linear-oblong in shape, obtuse at top; pedicel 0.3 cm.; cone scale very small, about 40 in number on a side.

Remarks: A single staminate cone from the Ogawa locality is closely similar to that of the modern *Keteleeria davidiana* BEISSN., and is included in *K. ezoana* which was originally described by winged seeds and cone scales from the Middle Miocene flora of southwestern Hokkaido.

The modern similar species, *K. davidiana* is living in central and southern China, and Formosa.

Occurrence: Ogawa, Kanagasawa loc. 1 and Miyano loc. 1, 2.

Collection: H.U.M.P., hypotypes nos. 26083, 26084.

Picea garoensis new species

Pl. 1, fig. 23

Description: Cone oblong, generally spindle-shaped, and slightly blending, 5 cm. long and 1.5 cm. wide; base and apex obtuse; upper part gradually narrow; cone scales crispate and obovate, about 0.7 cm. wide and 0.8 cm. high, about 15 steppes in arrangement; arrangement of cone scales in 3 : 5 conjugated parastichous rows.

Remarks: A single well-preserved cone from Garozawa is closely similar to those of the living *Picea maximowiczii* REGEL in its shape and size. It closely resembles a fossil cone figured as *P.* cf. *maximowiczii* from the Pliocene of northeastern Honshu (K. SUZUKI, 1961). The living equivalent, *P. maximowiczii*, is growing in the montane forest of central Honshu.

Occurrence: Garozawa.

Collection: H.U.M.P., holotype no. 26070.

Picea kaneharai TANAI and ONOE

Pl. 1, figs. 14, 15, 21, 22, 25, 26

Picea kaneharai TANAI and ONOE, Geol. Surv. Jap. Rep. no. 187, p. 17, pl. 1, fig. 9, 1961.

TANAI and N. SUZUKI, Paleont. Soc. Jap. spec. paper, no. 10, p. 3, pl. 7, figs. 2, 3 (see synonymy), 1965.

Remarks: Several winged seeds and two detached leaves are referred to *Picea kaneharai*. All of winged seeds figured as *P. magna* from the Miocene of southwestern Hokkaido (TANAI and N. SUZUKI, 1963) were included in *P. kaneharai* by authors (TANAI and N. SUZUKI, 1965). This species is closely related to the living *P. polita* in montane regions of central Honshu.

Occurrence: Ogawa, Garozawa, Kanagasawa loc. 1, 2, and Miyano loc. 2.

Collection: H.U.M.P., hypotypes nos. 26085-26088, 26148, 26149.

Picea kanoi HUZIOKA

Pl. 1, fig. 33

Picea kanoi HUZIOKA, HUZIOKA and NISHIDA, Publ. Sado Mus., no. 3, p. 10, pl. 1, fig. 1, 1960.

TANAI and N. SUZUKI, Tert Flora of Japan, p. 100, pl. 2, fig. 35, 1963.

Remarks: A single small winged seed has spatulate wing and an small, obovate-trigonal seed, and is referred to *P. kanoi*. This species is closely similar to the modern *P. koyamai* SHIRASAWA of central Honshu.

Occurrence: Kanagasawa loc. 1, 2.

Collection: H.U.M.P., hypotype no. 26089.

Picea ugoana HUZIOKA

Pl. 1, figs. 17-20

Picea ugoana HUZIOKA, HUZIOKA and NISHIDA, Publ. Sado Museum no. 3, pl. 10, pl. 1, fig. 1, 1960.

TANAI, Jour. Fac. Sci. Hokkaido Univ. Ser. 4, vol. 11, p. 252, pl. 1, fig. 20, 1961.

TANAI and N. SUZUKI, Tert. flora of Japan, p. 100, pl. 2, figs. 29, 30, 36-38; pl. 10, fig. 16b, 1963.

Remarks: Picea ugoana, represented by seeds, is commonly found in the Middle Miocene floras of southwestern Hokkaido and the Aniai-type floras of northeastern Honshu. It is closely similar to the modern *P. bicolor* MAYR. growing in the montane forest of central Honshu.

Occurrence: Ogawa, Garozawa and Kanagasawa loc. 1.

Collection: H.U.M.P., hypotypes nos. 26090-26093.

Pinus sp.

Remarks: A single needled leaf belongs probably to Pinus, and is similar to *P. miocenica* widely found in the Miocene of Japan. But this specimen is too fragmentary to assign its specific identification.

Occurrence: Ogawa.

Tsuga miocenica TANAI

Pl. 1, fig. 8

Tsuga miocenica TANAI, Jour. Fac. Sci. Hokkaido Univ. Ser. 4, vol. 11, p. 259, pl. 1, figs. 25, 26, 32, 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 103, pl. 1, figs. 13, 14; pl. 2, figs. 24-26, pl. 3, fig. 1, 1963.

Remarks: Three cone scales and two cones from Garozawa are assigned to *Tsuga miocenica* by the long bract. This species is closely related to modern *T. heterophylla* SARGENT of western North America, and *T. longibracteata* CHENG of southern China. *T. miocenica* is separable to *T. aburaensis* TANAI from the Abura flora and *T. oblonga* MIKI from Upper Miocene and Pliocene sediments of Honshu in size and shape.

Occurrence: Garozawa, Kanagasawa loc. 1, 2 and Miyano loc. 2.

Collection: H.U.M.P., hypotype no. 26071.

Family Taxodiaceae

Glyptostrobus europaeus (BRONGNIART) Heer

Pl. 1, fig. 27

Glyptostrobus europaeus (BRONG.) HEER, Flora Tertiary Helvetia, vol. 1, p. 51, pl. 19, figs. 1-6; pl. 20, figs. la-f, 1855.

ENDO and OKUTSU, Proc. Imp. Acad. Tokyo, vol. 12, p. 138, figs. 1-3, 1936.

TANAI and N. SUZUKI, Tert. Flora of Japan p. 103, pl. 3, figs. 11-13, 1963.

Remarks: Leafy shoots of *Glyptostrobus* are rarely found from the Ogawa locality, and are assigned to *G. europaeus,* which is common in Tertiary floras of the Northern Hemisphere. This species is comparable with the living *G. pensilis* KOCH. growing along river borders in southeastern China.

Occurrence: Ogawa.

Collection: H.U.M.P., hypotype no. 26094.

Family Taxodiaceae

Metasequoia occidentalis (NEWBERRY) CHANEY

Pl. 1, fig. 24

Matasequoia occidentalis (NEWBERRY) CHANEY, Trans. Amer. Phil. Soc., new ser., vol. 40, pt. 3, p. 225, pl. 1, fig. 3; pl. 2, figs. 1-3 and others, 1951.

TANAI, Jour. Fac. Sci., Hokkaido Univ., ser. 4, vol. 11, p. 263, pl. 3, figs. 1-8, 12, 14 (see synonymy), 1961.

Remarks: Several foliage shoots and a single cone from the Wakamatsu flora are referred to *Metasequoia occidentalis,* which is one of the most widely distributed conifers in the Tertiary of the Northern Hemisphere. Though this species is commonly found in the Miocene of Japan, it has been uncommon from Garo to Kudo areas.

Occurrence: Kanagasawa loc. 1, 2 and Miyano loc. 1, 2.

Collection: H.U.M.P., hypotype no. 26150.

Family Salicaceae

Populus nipponica TANAI and N. SUZUKI

Populus nipponica TANAI and N. SUZUKI, Tert. Flora of Japan, p. 106, pl. 4, figs. 3-5, 7 (see synonymy and discussion), 1963.

Remarks: Five fragmentary leaves from the Garo locality are referred to *Populus nipponica,* which was first described from the Kaminokuni flora in southwestern Hokkaido. It is closely similar to two poplars of North America: *P. canadicans* AIT. and *P. heterophylla* LINN.. The latter, the most similar species, is growing in the lower Mississippi Valley and Atlantic coast of the eastern United States.

Occurrence: Garozawa and Kanagasawa loc. 1.

Salix miosinica HU and CHANEY

Pl. 8, fig. 3

Salix miosinica HU and CHANEY, Paleont. Sinica New Ser. A, no. 1, pp. 25-26, pl. 4, figs. 4, 5, 1938.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 108, pl. 5, figs. 3-5, 1963.

Remarks: A single leaf of *Salix miosinica* is found from Garonosawa, and shows deniculate teeth in margin and lanceolate to oblong-obate in outline. This species is closely similar to the living *S. dictyoneura* V. SEEMEN and *S. wilsoni* SEEMEN of China, and *S. gracilistyla* MIQ. of northeastern Asia.

Occurrence: Garozawa.

Collection: H.U.M.P., hypotype no. 26073.

Family Myricaceae

Comptonia naumanni (NATHORST) HUZIOKA

Pl. 1, figs. 28-30

Comptonia naumanni (NATHORST) HUZIOKA, Jour. Min. Coll. Akita Univ., ser. 4, vol. 1, p. 65, pl. 3, figs. 7, 8 (see synonymy), 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 108, pl. 5, figs. 3-5, 1963.

Remarks: Incomplete leaves referred to *Comptonia naumanni* are abundant in the Ogawa locality. This species has been commonly found in the Middle Miocene through Japan. It is closely similar to the living *C. peregrina* (LINN.) COULT. of eastern North America.

Occurrence: Ogawa and Kanagasawa loc. 1.

Collection: H.U.M.P., hypotypes nos 26095-26097.

Family Juglandaceae

Carya miocathayensis HU and CHANEY

Pl. 1, figs. 31, 32

Carya miocathayensis HU and CHANEY, Paleont. Sinica, New Ser. A, no. 1, p. 26, pl. 6, fig. 1; pl. 7, figs. 5-7, 1938.

TANAI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, no. 2, p. 273, pl. 6, figs. 3, 4, 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 108, pl. 5, figs. 1, 2, 1963.

Remarks: Two incomplete leaflets are characterized by oblong to obovate shape and regular secondary veins, and are identified with *Carya miocathayensis.* It is closely similar to the living *C. cathayensis* SARG. of central and southern China.

Occurrence: Garozawa and Kanagasawa loc. 1.

Collection: H.U.M.P., hypotypes nos. 26074a, b.

Juglans japonica TANAI

Juglans japonica TANAI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, no. 2, p. 275, pl. 6, figs. 9, 10, (see synonymy) 1961.

Remarks: Eight specimens represented by fragmentary leaflets, are referred to *Juglans japonica* by their shape, venation and marginal teeth. This species is closely similar to the living *J. ailanthifolia* CARR. of East Asia.

Occurrence: Garozawa.

Pterocarya asymmetrosa KON'NO

pl. 1, figs. 1, 2

Pterocarya asymmetrosa KON'NO, Geol. of Central Shinano, pl. 16, figs. 5-7; pl. 17, figs. 1-5; pl. 17, figs. 3, 1931.

TANAI and N. SUZUKI, Palaeont. Soc. Jap. Spec. Paper, no. 10, p. 12, pl. 11, fig. 5; pl. 21, figs. 7, 8, 1965.

Pterocarya ezoana TANAI and N. SUZUKI. ISHIDA, Mem. Fac. Sci. Kyoto Univ., ser. Geol. & Min. vol. 37, no. 1, pl. 5, fig. 2 (not fig. 1a, b).

Remarks: Several leaflets, though incomplete and small, are identified with *Pterocarya asymmetrosa,* which is one of the common species in the Neogene of Japan. A single leaflet figured as *P. ezoana* from the Middle Miocene Noroshi flora of Noto peninsula (ISHIDA, 1970), is included in *P. asymmetrosa* by its secondary venetation character.

Occurrence: Ogawa and Garozawa.

Collection: H.U.M.P., hypotype no. 26098, 26099.

Pterocarya protostenoptera TANAI

Pl. 2, fig. 7

Pterocarya protostenoptera TANAI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 278, pl. 4, fig. 10 (see synonymy) 1961.

TANAI and N. SUZUKI, Palaeont. Soc. Jap. spec. paper, no. 10, p. 13, pl. 21, figs. 4, 5, 1965.

Remarks: Two slender leaflets from the Ogawa locality, though fragmentary, are surely identical with *Pterocarya protostenoptera* by slender secondary venation and oblong shape. This species is well characterized by two-winged nut, but no seed has been found in the Kudo flora and other Miocene floras of southwestern Hokkaido. *P. protostenoptera* is closely similar to the modern *P. stenoptera* DC. living in central and southern China.

Occurrence: Ogawa and Kanagasawa loc. 2.

Collection: H.U.M.P., hypotype no. 26100.

Family Betulaceae

Alnus protomaximowiczii TANAI

Pl. 2, figs. 8, 9

Alnus protomaximowiczii TANAI, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 11, p. 283, pl. 7, fig. 4, 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 111, pl. 5, figs. 8-10; pl. 7, figs. 5-7; pl. 8, fig. 9 (see synonymy and discussion), 1963.

Alnus rikuchuensis MURAI, Rep. Techn. Iwate Univ., vol. 15, no. 2, p. 19, pl. 6, fig. 1, 1962.

Remarks: Our leaves are variable in size, general outline, basal form and marginal teeth and texture. They vary from double-serrate to crenate teeth, and from thin to firm texture. These leaves are closely similar to those produced by the modern *Alnus maximowiczii* CALL., which widely grows in the cool-temperate regions of northeastern Asia. *A. rikuchuensis* described from the Late Miocene Shizukuishi flora of Iwate Prefecture (MURAI, 1962), is unseparable from our species, and is conspecific with *A. protomaximowiczii.*

Occurrence: Ogawa, Kanagasawa loc. 1, 2 and Miyano loc. 1, 2.

Collection: H.U.M.P., hypotypes nos. 26101, 26151.

Alnus usyuensis HUZIOKA

Alnus usyuensis HUZIOKA. TANAI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, no. 2, p. 283, pl. 6, figs. 12, 13; pl. 7, figs. 2, 5, 6; pl. 9, fig. 8 (see synonymy), 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 112, pl. 7, figs. 1, 2, 8, 1963.

Remarks: Two fragmentary leaves of *Alnus usyuensis* are found from the Garozawa locality. They resemble several modern alder species, *Alnus sitchensis* (REGEL) SARG. on the Pacific slope of North America, *A. hirsuta* TURCZ. of Japan and *A. incana* WILD. of Europe, and especially close to the first.

Occurrence: Garozawa.

Betula uzenensis TANAI

Betula uzenensis TANAI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 291, pl. 8, figs. 7, 9, 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 115, pl. 7, figs. 3, 6; pl. 8, figs. 4-6, 10, 11; pl. 10, fig. 2, 1963.

Remarks: A single leaf and winged seed from the Garo flora are referable to *Betula uzenensis,* which is similar to *B. grossa* SIEB. and ZUCC., and *B. schmidti* REGEL. These two modern birches are growing in the montane and upland forest of Japan. *B. uzenensis* was reported from Kaminokuni and Kayanuma floras in southwestern Hokkaido by us.

Occurrence: Garozawa.

Carpinus miocenica TANAI

Pl. 2, fig. 3

Carpinus miocenica TANAI, Geol. Surv. Japan. Rep., no. 163, pl. 5, figs. 1, 2, 1955.

TANAI and ONOE, Geol. Surv. Japan Rep. no. 187, p. 26, pl. 3, fig. 3; pl. 4, fig. 4, 1961.

Remarks: A nearly complete leaf from the Ogawa locality is identical with *Carpinus miocenica,* which was reported from the Middle Miocene and the Upper Miocene of Japan. It is closely related to the modern *C. laxiflora* BLUME widely growing in Japan, and also resembles *C. londoniana* WINK. of Yunnan in Southeastern China.

Occurrence: Ogawa.

Collection: H.U.M.P., hypotype no. 260102.

Carpinus miofangiana HU and CHANEY

Pl. 2, fig. 4

Carpinus miofangiana HU and CHANEY, Palaeont. Sinica, New Ser. A, no. 1, p. 32, pl. 10, figs. 2, 3, 1938.

Tanai and N. Suzuki, Tert. Flora of Japan, p. 116, pl. 9, figs. 1, 11, 1963.

Remarks: A single incomplete leaf from the Miyano locality (no. 2) is large in size and numerous in secondary veins, and is referred to *Carpinus miofangiana.* This species has been uncommonly known in the Miocene of southwestern Hokkaido and Honshu. It is closely related to the modern *C. fangiana* HU living in central and southwestern China.

Occurrence: Miyano loc. 2 and Kanagasawa loc. 1.

Collection: H.U.M.P., hypotype no. 26015.

Carpinus mioturczaninovii HU and CHANEY

Pl. 3, figs. 4-7

Carpinus mioturczaninovii HU and CHANEY, Palaeont. Sinica, New Ser. A, no. 1, p. 33, pl. 9, fig. 7 (excluding figs. 2, 6), 1938.

ISHIDA, Mem Fac. Sci. Kyoto Univ., vol. 37, no. 1, p. 73, pl. 6, figs. 4, 7 (see synonymy), 1970.

Remarks: Our leaves and bracts from the Miyano and Kanagasawa localities are fairly identical with *Carpinus mioturczaninovii,* which was recently redesignated on the basis of leaves and bracts from the Miocene Noroshi flora of Noto peninsula (ISHIDA, 1970). This species is closely similar to the modern *C. turczaninovii* HANCE living in northern and central China, extending into Japan and Korea. *C. mioturczaninovii* was originally established from the Miocene Shanwang flora (HU and CHANEY, 1938) on the basis of leaves and bracts, but the Shanwang leaves are not similar to *C. truczaninovii.*

Occurrence: Miyano loc. 1, 2 and Kanagasawa loc. 2.

Collection: H.U.M.P., hypotypes nos. 26153, 26154, 26161, 26162.

Carpinus subcordata NATHORST

Pl. 2, figs. 5, 6, 11-13.

Carpinus subcordata NATHORST, Kgl. Svensk, Vet-Akad. Handl. Bd. 20, no. 2, p. 39, pl. 2, figs. 13-18, 20, 1883.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 117, pl. 7, fig. 4, pl. 9, figs. 2-5, 12, 13 (see synonymy and discussion), 1963.

Supplementary description: Material nutlet, 4 mm. long and 6 mm. wide, ellipsoidal or ovoid in shape, about 10 striae on a side, base round with small contact point, top acute.

Remarks: *Carpinus subcordata* is one of the common species in the Neogene of East Asia, and is represented by leaves and an involucre from the Garozawa and Ogawa localities. Four well-preserved nutlets, though they are impressions, are closely similar to those of the modern *C. cordata*, and are included in *C. subcordata*. The modern equivalent, *C. cordata* BLUME is widely distributed in Japan and China.

Occurrence: Garozawa, Ogawa, Kanagasawa loc. 1, 2 and Miyano loc. 1, 2.

Collection: H.U.M.P., hypotypes nos. 26103-26107.

Carpinus subyedoensis KON'NO

Pl. 3, figs. 1-3

Carpinus subyedoensis KON'NO, Geol. of Central Shinano, pl. 8, figs. 1-4, 1931.

TANAI and ONOE, Geol. Surv. Jap. Rep., no. 187, p. 29, pl. 4, figs. 3, 6, 7, 10 (see synonymy), 1961.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 118, pl. 9, figs. 6, 9, 10, 15; pl. 10, fig. 6, 1963.

Remarks: This species is represented by many well-preserved leaves and a bract from the Ogawa locality, all of which specimens are close to those of the modern *Carpinus tschonoskii* MAXIM.. *C. subyedoensis* has been commonly found in the Neogene of Honshu, but has been not always common in the Miocene of Hokkaido. The similar living species, *C. tschonoskii,* is widely growing from Honshu to Kyushu, extending into Korea and central China.

Occurrence: Ogawa, Kanagasawa loc. 1 and Miyano loc. 1.

Collection: H.U.M.P., hypotypes nos. 26108, 26163, 26164.

Corylus macquarrii (FORBES) HEER

Pl. 4, figs. 1, 2

Corylus macquarrii (FORBES) HEER, Naturf. Ges. Zürich, vierteljahrssch., vol. 7, p. 178, 1862.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 119, pl. 11, figs. 2, 4, 6, 8, 9, 1963.

Supplementary description: Nut compressed, flattened, about 1 cm. long and wide, many fine striae running longitudinally, and with 8 strong striate irregularly; top obtuse and base truncate agaist striae.

Remarks: Several leaves, though ill-preserved, are identified to *Corylus macquarrii,* which has been widely reported from the Tertiary of the Northern Hemisphere. As already pointed out by the authors (TANAI and N. SUZUKI, 1963), this species is highly variable in foliage shape, and has been abused by many authors. *C. macquarrii* is distinguishable in secondary venation from *C. ezoana* recently established from the Oligocene of southeastern Hokkaido by the senior author (TANAI, 1970).

Associated with leaves, two compressed nuts from the Garo and Ogawa localities closely resemble those of the modern *C. heterophylla* FISCH., and is included in *C. macquarrii*. The living equivalent, *C. heterophylla*, is widely distributed in the temperate hardwood forest of East Asia.

Occurrence: Ogawa and Garozawa.

Collection: H.U.M.P., hypotypes nos. 26109, 26110.

Ostrya shiragiana HUZIOKA

Pl. 4, figs. 3, 4

Ostrya shiragiana HUZIOKA, Trans. Proc. Paleont. Soc. Jap. N. S., no. 3, p. 121, pl. 13, figs. 7, 8, 1954.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 119, pl. 11, figs. 1, 3, 5, 7 (see synonymy), 1963.

Remarks: *Ostrya shiragiana* represented by several incomplete leaves and a bract from two localities, is closely similar to the modern *O. japonica* SARG. growing from Hokkaido to Kyushu, and to *O. virginiana* (MILL.) KOCH. of the United States.

Occurrence: Garozawa and Kanagasawa loc. 2.

Collection: H.U.M.P., hypotypes nos. 26075, 26156.

Family Fagaceae

Castanea miomollissima HU and CHANEY

Pl. 3, fig. 9

Castanea miomollissima HU and CHANEY, Palaeont. Sinica, New Ser. A, no. 1, p. 35, pl. 13, figs. 3, 7, 1938.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 120, pl. 12, figs. 3, 4; pl. 14, figs. 4-6; pl. 15, figs. 1, 2, 5, 6, 1963.

Remarks: A number of well-preserved leaves from the Wakamatsu flora are identical with *Castanea miomollissima*, which is common in the Middle Miocene of Honshu and southwestern Hokkaido.

Occurrence: Miyano loc. 1, 2 and Kanagasawa loc. 1, 2.

Collection: H.U.M.P., hypotype no. 26166.

Fagus antipofi HEER

Pl. 2, fig. 10; pl. 5, figs. 1-5

Fagus antipofi HEER, Acad. Imp; Sci. St-petersb. Mem. Ser. 6, vol. 7, p. 572, pl. 8, fig. 2, 1858.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 121, pl. 13, figs. 1-7, 1963.

Remarks: A number of beech leaves, associated with several involucres and bud scales, are collected from the Ogawa locality, and are referred to *Fagus antipofi* which is common in the Lower and Middle of the Northern Hemisphere. In the ratio of length to maximum width (leaf index) and number of secondary veins, *F. antipofi* is distinguishable from other Neogene beeches of East Asia (TANAI, 1971). *F. antipofi* is closely related with the modern *F. grandifolia* EHR. of eastern North America.

Occurrence: Ogawa, Kanagasawa loc. 1, 2 and Miyano loc. 1, 2.

Collection: H.U.M.P., hypotypes nos. 26111-26115, 26152.

Quercus miovariabilis HU and CHANEY
Pl. 3, figs. 8, 10, 11

Quercus miovariabilis HU and CHANEY, Palaeont. Sinica, New Ser. A, no. 1, p. 36, pl. 15, figs. 5, 6, 1938.

ISHIDA, Mem. Fac. Sci. Kyoto Univ., vol. 37, no. 1, p. 77, pl. 8, figs. 2, 3, 6, 7, 1970.

Remarks: It is very difficult to distinguish certain leaves of *Quercus* from *Castanea* on the basis of only fossil foliage character. As already discussed by the authors (TANAI and N. SUZUKI, 1963) and ISHIDA (1970), *Quercus miovariabilis* is frequently difficult to separate from *Castanea miomollissima*, and these two species has been sometimes confused. The authors consider that *Q. miovariabilis* is generally narrower in shape and smaller in marginal teeth than *C. miomollissima*. Many leaves from new localities of the Wakamatsu flora are tentatively referred to *Q. miovariabilis*, based on the above-noted criteria, but they have to be further investigated in detail.

Occurrence: Kanagasawa loc. 2 and Miyano loc. 1, 2.

Collection: H.U.M.P., hypotypes nos. 26155, 26167, 26168.

Family Ulmaceae
Ulmus carpinoides GOEPPERT
Pl. 4, fig. 5

Ulmus carpinoides GOEPPERT, Braunkholenfl. nordost. Deutsch. p. 492, 1852.

TANAI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, no. 2, p. 317, pl. 17, fig. 2 (see synonymy), 1961.

Remarks; A single well-preserved leaf with a slightly asymmetrical shape, cordate base and doubly serrate margin, represents elm, though it has no forking secondary veins. It closely resembles *Ulmus carpinoides* which has been described from the Tertiary of Europe.

Occurrence: Ogawa.

Collection: .H.U.M.P., Hypotype no. 26116.

Ulmus longifolia UNGER

Ulmus longifolia UNGER, Chlor. protog. Taf. 26, figs. 5, 6, 1847.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 123, pl. 16, figs. 1, 2, 1963.

Remarks: Four leaves characterized by lanceolate shape, slender secondaries, equal-size marginal teeth and slightly cordate base, and are referable to *U. longifolia*. There is no living elm closely similar to this species in the North Hemisphere.

Occurrence: Garozawa and Kanagasawa loc. 1, 2.

Ulmus shiragica HUZIOKA

Ulmus shiragica HUZIOKA, Trans. Proc. Paleont. Soc. Jap., N.S. no. 3, p. 70, pl. 5, fig. 8, pl. 6, fig. 6, 1951.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 123, pl. 16, fig. 3, 1963.

Remarks: Six elm leaves with ovate shape are referred to *Ulmus shiragica,* which is closely similar to the modern *U. davidiana* PLANCH. of China.

Occurrence: Garozawa.

Zelkova ungeri KOVATS

Pl. 6, figs. 1-4

Zelkova ungeri KOVATS, Jahrb. d, k. k. Geol. Reichsanst., p. 178, 1851.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 124, pl. 17, fig. 1-12; pl. 18, figs. 1-8; pl. 19, figs. 3, 6 (see synonymy), 1963.

Remarks: Zelkova ungeri, widely distributed in the Tertiary of Eurasia, is also one of the common species in the Miocene of southwestern Hokkaido. A number of well-preserved leaves referred to this species were collected from the Kanagasawa and Miyano localities.

Occurrence: Ogawa, Kanagasawa loc. 1, 2 and Miyano loc. 1, 2.

Collection: H.U.M.P., hypotypes nos. 26117-26120.

Family Cercidiphyllaceae

Cercidiphyllum crenatum (UNGER) BROWN

Cercidiphyllum crenatum (UNGER) BROWN, Jour. Paleont. vol. 9, p. 575, 1935.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 124, pl. 4, fig. 2; pl. 16, fig. 11; pl. 21, fig. 6, 1963.

Remarks: Three fragmentary leaves referred to this species have been found from Garozawa. This species is closely similar to the modern *Cercidiphyllum japonicum* SIEB. and ZUCC. living in Hokkaido and northeastern Honshu.

Occurrence: Garozawa, Ogawa and Kanagasawa loc. 1.

Family Eucommiaceae

Eucommia japonica TANAI

Pl. 4, figs. 8-11

Eucommia japonica TANAI, Jour. Fac. Sci. Hokkaido Univ., Ser. 4, vol. 11, no. 2, p. 329, pl. 21, fig. 3 (see synonymy), 1961.

ISHIDA, Mem. Fac. Sci., Kyoto Univ., Ser. Geol. & Min. vol. 37, no. 1, p. 87, pl. 14, figs. 2, 3, 1970.

Supplementary description: Leaf incomplete, 3.5 cm. wide, length unknown; base round and slightly asymmetrical; apex missing; midrib slender and straight; secondaries opposite and subalternate, 6 to 7 in number, forming small loops near the margin, diverging from secondaries at angles of 45 to 50 degrees; tertiaries irregularly percurrent, trending transversely to secondaries; marginal teeth dentato-creanate with small glands at the tip of teeth; petiole 1 cm. long.

Remarks: Several capsules from the Ogawa and Kanagasawa (no. 2) localities are identified to *Eucommia japonica* by their characteristic features. A single leaf, though incomplete, have small marginal teeth with glands and distinct looping of secondary venation, and is closely similar to small leaves of the modern *E. ulmoides* OLIVER. This fossil leaf is included in *E. japonica* which was originally described only by capsules. Our fossil leaf somewhat resembles *E. serrate* (NEWB.) BROWN described from the Paleocene of western North America (BROWN, 1962), though leaves of this American species are highly variable in shape and size. *E. japonica* is closely similar to the modern *E. ulmoides* (Pl. 4, figs. 6, 7), a monotypic tree, living in central China.

Occurrence: Ogawa and Kanagasawa loc. 2.

Collection: H.U.M.P., hypotypes nos. 26121-26124.

Family Liguminosae

Cercis miochinensis HU and CHANEY

Pl. 7, figs. 11, 12

Cercis miochinensis HU and CHANEY, Palaeont. Sinica, New Ser. A, no. 1, p. 51, pl. 26, figs. 1, 3, 5; pl. 27, fig. 5, 1938.

TANAI and N. SUZUKI. Tert. Flora of Japan, p. 132, pl. 21, fig. 4, 1963.

Remarks: Two fragmentary leaves and a legumen pod are fairly identical with *Cercis miochinensis,* which is closely related to the modern *C. chinensis* BUNG. of China. *C. miochinensis* has been uncommon in the Tertiary of East Asia.

Occurrence: Miyano loc. 1, 2.
Collection: H.U.M.P., hypotypes nos. 26144, 26170.

Gleditsia miosinensis HU and CHANEY
Pl. 4, fig. 13

Gleditsia miosinensis HU and CHANEY. Paleont. Sinica, New Ser. no. 1, p. 52, pl. 26, figs. 6, 7, 1938.
TANAI *and N.* SUZUKI, *Tert. Flora of Japan, p. 132, pl. 15, fig. 9; pl. 23, figs. 2, 10, 1963.*

Remarks: Two leaflets from the Ogawa locality are slightly crenato-serrate in margin and lanceolate to oblong in shape, and are referred to *Gleditsia miosinensis.* This species is similar to the modern *G. sinensis* LAMARCK of central and northern China.

Occurrence: Ogawa.
Collection: H.U.M.P., hypotype no. 26125.

Pueraria miothunbergiana HU and CHANEY
Pl. 4, fig. 14

Pueraria miothunbergiana HU and CHANEY, Paleont. Sinica New Ser. no. 1, p. 52, pl. 28, fig. 1, 1938.

Remarks: A single leaflet has three-lobed shape, entire but somewhat undulate margin, distinct secondary veins forming loop along the margin, and stout petiole. This specimen, though incomplete, represents a lateral leaflet of *Pueraria miothunbergiana,* which was originally described by a terminal leaflet from the Miocene Shanwang flora of China (HU and CHANEY, 1938). This species is closely similar to the modern *P. thunbergiana* BENTHAM widely distributed in East Asia.

Occurrence: Ogawa.
Collection: H.U.M.P., hypotype no. 26126.

Family Rutaceae

Phellodendron mioamurense TANAI and N. SUZUKI
Pl. 6, fig. 5

Phellodendron mioamurense TANAI and N. SUZUKI, Tert. Flora of Japan, p. 134, pl. 22, fig. 10, 1963.

Remarks: A complete leaflet and its counterpart have an elliptical shape, asymmetrical base, rather thin secondaries that arch well upward along the margin, and nearly entire margin. This fossil is identical with *Phellodendron mioamurense* which was described from the Miocene of Hokkaido. It is closely related to the modern *P. amurense* RUPR. widely distributed in northeastern

Asia.

Occurrence: Kanagasawa loc. 2.

Collection: H.U.M.P., hypotype no. 26147.

Family Anacardiaceae

Rhus miosuccedanea HU and CHANEY

Pl. 6, figs. 6, 7

Rhus miosuccedanea HU and CHANEY, Paleont. Sinica New Ser. A, no. 1, p. 63, pl. 35, fig. 3b; pl. 36, figs. 6, 8; pl. 37, figs. 1-3, 1938.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 135, pl. 22, figs. 3, 5, 6, 8, 1963.

Remarks: A single leaflet has asymmetrically acute base and characteristic secondary veins, and is referred to as *Rhus miosuccedanea.* It is closely similar to the modern *R. succedanea* LINNE. distributed in central and southern China, Malaysia, Formosa, India and southern Japan. This species is common in the Yoshioka and Wakamatsu floras of southwestern Hokkaido.

Occurrence: Ogawa and Kanagasawa loc. 1.

Collection: H.U.M.P., hypotypes nos. 26127a, b.

Family Aceraceae

Acer ezoanum OISHI and HUZIOKA

Pl. 7, figs. 1-5

Acer ezoanum OISHI and HUZIOKA, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 7, p. 89, pl. 10, figs. 1-4; pl. 11, figs. 1-4; pl. 12 fig. 2, 1943.

TANAI and N. SUZUKI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 10, p. 556, pl. 1, figs. 1, 2; pl. 2, figs. 1, 2; pl. 3, figs. 1-4; pl. 9, figs. 20-25 (see synonymy), 1960.

Remarks: This species represented by a number of leaves and samaras, is characterized by unstable foliage shape, prominent and irregular dents in each lobe, and the winged fruits with extension angles of 180 degrees or more. *Acer ezoanum* is closely related to the living *A. miyabei* MAXIM. distributed in northern Japan.

Occurrence: Ogawa and Kanagasawa loc. 1, 2.

Collections: H.U.M.P., hypotypes nos. 26146, 26128, 26130-26132.

Acer miodavidii HU and CHANEY

Pl. 8, fig. 1

Acer miodavidii HU and CHANEY, Paleont. Sinica, New Ser. A, no. 1, p. 58, pl. 32, figs. 1, 3, 5, 1938.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 139, pl. 21, fig. 8, 1963.

Remarks: The specimens are, though incomplete, identical with *Acer miodavidii* in having stout secondary veins and an irregularly compound-serrate margin. No fossil samara referred to this species has been found in the Tertiary of Japan. *A. miodavidii* is comparable with the modern *A. davidii* FRANCH. of China.

Occurrence: Garozawa.

Collection: H.U.M.P., hypotype no. 26076.

Acer miohenryi HU and CHANEY

Pl. 6, fig. 10

Acer miohenryi HU and CHANEY (in part), Palaeont. Sinica, New Ser. A, p. 59, pl. 33, figs. 1, 3, 6; pl. 34, fig. 2; pl. 35, figs. 2, 4, 1938.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 141, pl. 25,figs. 4, 8 (see synonymy), 1963.

Remarks: Several detached leaflets from the Wakamatsu flora are identified to Acer miohenryi by the large marginal dents and secondary venation character. The leaflets of box-elder type have been rather commonly found in the Middle Miocene of southwestern Hokkaido and Honshu. *A. miohenryi* is closely similar to the modern *A. henryi* PAX of China and *A. negundo* LINN. of North America, especially closer to the latter.

Occurrence: Ogawa, Kanagasawa loc. 1, 2 and Miyano loc. 1, 2.

Collection: H.U.M.P., hypotype no. 26159.

Acer protodistylum ENDO

Pl. 6, fig. 8

Acer protodistylum ENDO, Short Papers IGPS, no. 1, p. 12,pl. 3, fig. 2, 1950.

TANAI and N. SUZUKI, Jour. Fac. Sci., Hokkaido Univ., ser. 4, vol. 10, p. 564, pl. 9, figs. 3, 4, 1960.

Remarks: A single samara is refered to *Acer protodistylum* by its shape of wing and the extension angle. This species has been uncommon in the Tertiary of Japan.

Occurrence: Kanagasawa loc. 2.

Collection: H.U.M.P., hypotype no. 26157.

Acer protojaponicum TANAI and ONOE

Acer protojaponicum TANAI and ONOE, Bull. Geol. Surv. Jap., vol. 10, no 4, p. 281, pl. 6, figs. 5-7, 1959.

TANAI and N. SUZUKI, Jour, Fac. Sci. Hokkaido Univ., ser, 4, vol. 10, p. 565, pl. 5, fig. 4; pl. 9, figs. 18, 19, 1960.

Remarks: A single samara is referred to *Acer protojaponicum* by the shape and extention angles of wing. The leaves and samaras of this species is comparatively common in the Middle Miocene of southwestern Hokkaido. It is closely similar to the modern *A. japonicum* THUNB. growing in Hokkaido and Honshu.

Occurrence: Ogawa and Kanagasawa loc. 1.

Acer prototataricum TANAI and N. SUZUKI

Pl. 6, fig. 9

Acer prototataricum TANAI and N. SUZUKI, Jour. Fac. Sci., Hokkaido Univ., ser. 4, vol. 10, p. 566, pl. 9, figs. 7, 12.

Remarks: A single samara has strongly curved wing and bulged, semicircular seeds, and is identical with *Acer prototataricum,* which was originally described from the Miocene Yoshioka and Abura floras of southwestern Hokkaido. This species is closely similar to the modern *A. tataricum* LINN. of northern China and Manchuria.

Occurrence: Kanagasawa loc. 2.

Collection: H.U.M.P., hypotype no. 26158.

Acer pseudoginnala TANAI and ONOE

Pl. 6, figs. 14, 15.

Acer pseudoginnala TANAI and ONOE, Bull. Geol. Surv. Japan, vol. 10, no. 4, p. 281, pl. 6, figs. 1, 13, 1959.

TANAI and N. SUZUKI, Jour. Fac. Sci., Hokkaido Univ., ser. 4, vol. 10, p. 566, pl. 9, figs. 13-16, 1960.

Remarks: Several samaras from the Wakamatsu flora, though somewhat incomplete, are referred to *Acer pseudoginnala* by characteristic shape of seeds and extension angles of wings. This species closely resembles the modern *A. ginnala* MAXIM. widely distributed in northeastern Asia.

Occurrence: Kanagasawa loc. 1, 2 and Miyano loc. 2.

Collection: H.U.M.P., hypotypes nos. 26160, 26160.

Acer subpictum SAPORTA

Pl. 7, figs. 6-9; pl. 8, fig. 2

Acer subpictum SAPORTA. TANAI and N. SUZUKI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 10, p. 567, pl. 4, figs. 1-4; pl. 7, figs. 3-6, (see synonymy) 1960.

Acer submayrii TANAI and ONOE, Geol. Surv. Jap. Rep. no. 187, pl. 17, fig. 5, 1961.

TANAI and N. SUZUKI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 10, p. 568, pl. 9, fig. 9, 1960.

Acer mayrii SCHWER. ENDO, Short Papers IGPS, no. 3, p. 57, pl. 8, fig. 5, 1961.

Remarks: A number of leaves and samaras are identical with *Acer subpictum*, which is one of the common maples in the Tertiary of Eurasia. This species is closely related to the modern *A. mono* MAXIM. widely distributed in the temperate forest of northeastern Asia. Samaras of *A. subpictum* are somewhat variable in shape, size and extension angles of wings as do similarly by the living equivalent, *A. mono*. Several samaras described as *A. submayrii* from the Miocene of Honshu and southwestern Hokkaido, are unseparable from those of *A. subpictum*, and are probably conspecific.

Occurrence: Ogawa, Garozawa, Kanagasawa loc. 1 and Miyano loc. 2.

Collection: H.U.M.P., hypotypes nos. 26077, 26133-26136.

Acer yoshiokaense TANAI and N. SUZUKI

Pl. 6, figs. 11-13

Acer yoshiokaense TANAI and N. SUZUKI, Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 10, p. 568, pl. 2, figs. 4-6, 1960.

Remarks: The present samaras are referred to *Acer yoshiokaense*, which resembles the modern *A. saccharum* MARSH. in general outline of wing and bulged seed.

Occurrence: Ogawa.

Collection: H.U.M.P., hypotypes nos. 26137-26139.

Family Alangiaceae

Alangium aequalifolium (GOEPPERT) KRYSHTOFOVICH and BORSUK

Alangium aequalifolium (GOEPPERT) KRYSHTOFOVICH and BORSUK, Prob. Pal., vol. 5, p. 390, pl. 5, figs. 1-8; pl. 6, figs. 6, 7, 1939.

HUZIOKA, Tert. Flora of Japan, p. 212, pl. 38, fig. 9 (see synomyny), 1963.

Remarks: This species is very rare in the Middle Miocene of southwestern Hokkaido. It is similar to the modern *Alangium platanifolium* (SIEB. and ZUCC.) of Japan and China.

Occurrence: Garozawa and Miyano loc. 2.

Family Tiliaceae

Tilia protojaponica ENDO

Pl. 4, fig. 12; pl. 8, figs. 5-8

Tilia protojaponica ENDO, Icones, Fos. Plant East Asia, pl. 27, fig. 1, 1955.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 143, p. 26, figs. 1-3, 5 (see synonymy), 1963.

Remarks: A number of leaves, though mostly fragmentary, are referred to

Tilia protojaponica by secondary venation and marginal characters. This species is closely similar to the modern *T. japonica* widely distributed in East Asia. Four bracteoles, associated with these fossil leaves, are identical with those of the modern *T. japonica,* and are included in *T. protojaponica.*

Occurrence: Ogawa, Garozawa and Kanagasawa loc. 1.

Collections: H.U.M.P., hypotypes nos. 26078-26081, 26140.

Family Hydrocaryaceae

Hemitrapa borealis (HEER) MIKI

Pl. 5, figs. 6, 7

Hemitrapa borealis (HEER) MIKI, Palaeobotanist vol. 1, p. 349, Text-fig. 2A, 1952.

TANAI and N. SUZUKI, Tert. Flora of Japan, p. 145, pl. 10, figs. 18, 19, 1963.

Remarks: A number of nuts have spindle shape and two appendages, and are identical with *Hemitrapa borealis.* This species is common in the Miocene of Honshu and southwestern Hokkaido.

Occurrence: Ogawa, Garozawa and Kanagasawa loc. 1.

Collection: H.U.M.P., hypotypes nos. 26141, 26142.

Trapa ezoana TANAI and N. SUZUKI

Pl. 8, fig. 4

Trapa ezoana TANAI and N. SUZUKI, Tert. Flora of Japan, p. 145, pl. 10, fig. 14, 1963.

Remarks: This nut is somewhat ill-preserved, small and 2-armed in shape, and is referred to *Trapa ezoana,* which was described from the Kaminokuni flora of southwestern Hokkaido. This species is comparable with *T. silesiaca* GOEPPERT from Neogene flora of Germany, but somewhat differs in the shape.

Occurrence: Garozawa.

Collection: H.U.M.P., hypotype no. 26082.

Family Oleaceae

Fraxinus wakamatsuensis TANAI and N. SUZUKI

Pl. 7, fig. 10

Fraxinus wakamatsuensis TANAI and N. SUZUKI, Tert. Flora of Japan, pp. 147, 148, pl. 25, figs. 2, 3, 1963.

Remarks: A single samara having a lanceolate seed with incomplete wing, is referred to Fraxinus wakamatsuensis, which was established from on the basis of samara from the Wakamatsu flora (TANAI and N. SUZUKI, 1963). An incomplete leaflet from the Garozawa represents *Fraxinus* in its secondary venation and margin, and is probably included in this species.

Occurrence: Ogawa, Garozawa and Kanagasawa loc. 1.
Collection: H.U.M.P., hypotype no. 26143.

Insertae Sedis

Carpolithes japonica (MORITA) ISHIDA

Pl. 7, figs. 13, 14, 15

Carpolithes japonica (MORITA), ISHIDA, Mem. Fac. Sci. Kyoto Univ. vol. 37, no. 1, p. 103, pl. 22, figs. 1, 2, 6, 7, 1970.

Dodonaea japonica (MORITA) TANAI, Jour. Fac. Sci., Hokkaido Univ., ser. 4, vol. 11, p. 352, pl. 24, fig. 15, 1961.

Remarks: Two winged seeds and their counterparts are closely similar to the capsules of *Dodonaea japonica,* which the senior author (TANAI, 1961) has described in the Middle Miocene of Honshu and Korea. Recently ISHIDA (1970) pointed out that these specimens were different from *Dodonaea* on the basis of his collection from the Miocene Noroshi flora. The authors must make a further investigation for these specimens in detail.

Occurrence: Ogawa and Garozawa.
Collection: H.U.M.P., hypotypes nos. 26145a, b, 26146.

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PLATES 1～8 AND EXPLANATION

Explanation of Plate 1

Figs. 1, 2 *Osmunda sachalinensis* KRYSHTOFOVICH. Hypotypes, H.U.M.P., Reg. nos. 26061, 26062. Garozawa.

Fig. 3-5 *Abies aburaensis* TANAI. Hypotypes, H.U.M.P., Reg. nos. 26063, 26064, 26065. Garozawa.

Figs. 6, 7 *Abies homolepis* SIEB. and ZUCC..Cone sclae of the living species for comparison. fig. 6: Inside, fig. 7: outside with bract.

Fig. 8 *Tsuga miocenica* TANAI. Hypotype, H.U.M.P., Reg. no. 26071. Garozawa.

Figs. 9, 16 *Keteleeria ezoana* TANAI. Hypotypes, H.U.M.P., Reg. nos. 26083, 26084. Ogawa. x 2

Figs. 10-13 *Abies n-suzukii* TANAI. Hypotypes, H.U.M.P., Reg. nos. 26066, 26067, 26068, 26069. Garozawa.

Figs. 14, 15, 21, 22 *Picea kaneharai* TANAI and ONOE. Hypotypes, H.U.M.P., Reg. nos. 26085, 26086, 26087, 26088. Ogawa.

Figs. 17-20 *Picea ugoana* HUZIOKA. Hypotypes, H.U.M.P., Reg. nos. 26090, 26091, 26092, 26093. Ogawa.

Fig. 23 *Picea garoensis* new species. Holotype, H.U.M.P., Reg. no. 26070. Garozawa.

Fig. 24 *Metasequoia occidentalis* (NEWBERRY) CHANEY. Hypotype, H.U.M.P., Reg. no. 26150. Miyano loc. 2.

Figs. 25, 26 *Picea kaneharai* TANAI and ONOE. Hypotypes, H.U.M.P., Reg. nos. 26148, 26149. Kanagasawa loc. 2.

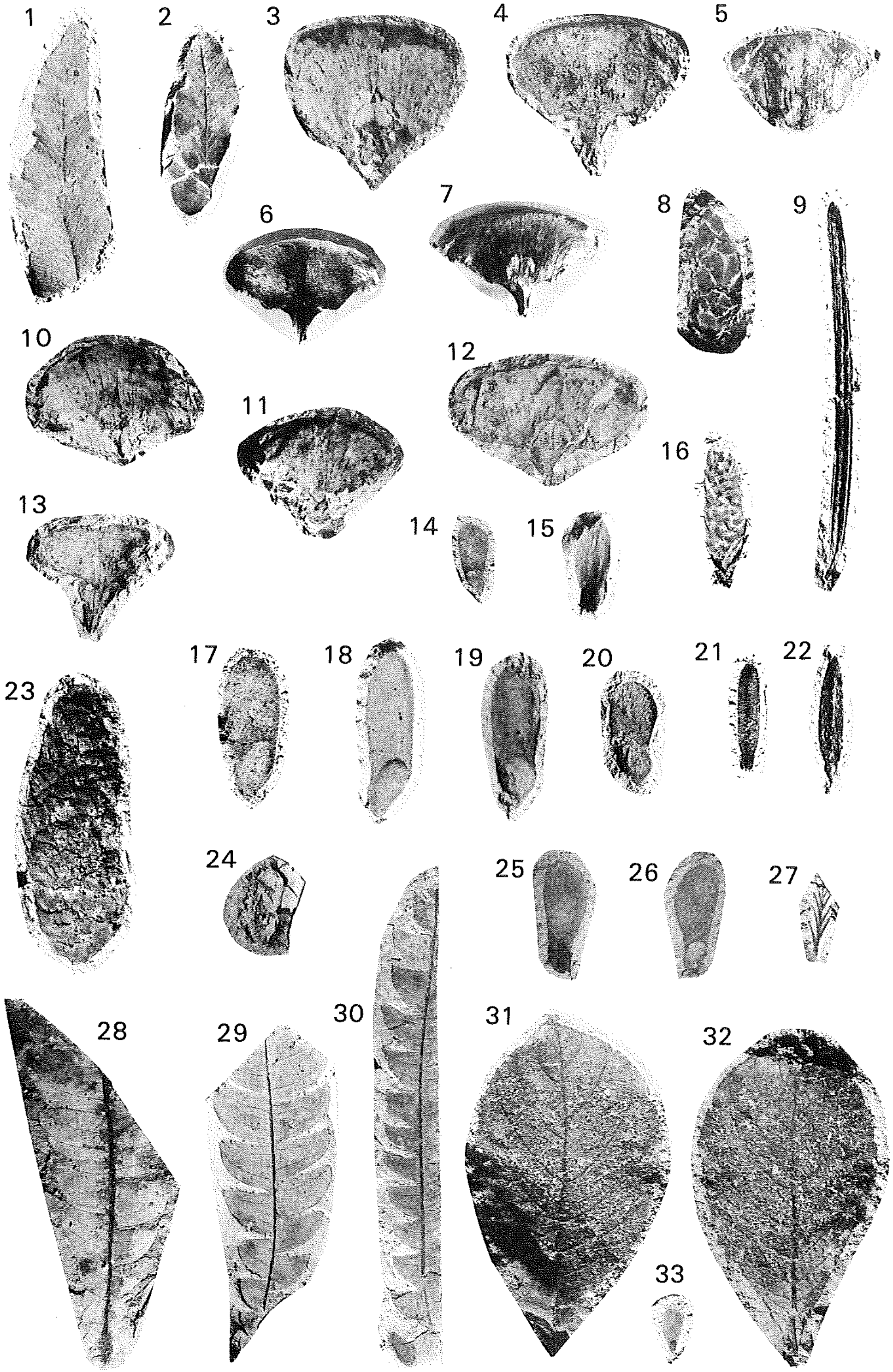
Fig. 27 *Glyptostrobus europaeus* (BRONGNIART) HEER. Hypotype, H.U.M.P., Reg. no. 26094. Ogawa.

Figs. 28-30 *Comptonia naumanni* (NATHORST)HUZIOKA. Hypotypes, H.U.M.P., Reg. nos. 26095, 26096, 26097. Ogawa.

Figs. 31, 32 *Carya miocathayensis* HU and CHANEY.Hypotype, H.U.M.P., Reg. no. 26074a, b. Garozawa.

Fig. 33 *Picea kanoi* HUZIOKA. Hypotype, H.U.M.P., Reg. no. 26089. Ogawa.

Plate 1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Explanation of Plate 2

Figs. 1, 2 *Pterocarya asymmetrosa* KON'NO. Hypotypes, H.U.M.P., Reg. nos. 26098, 26099. Ogawa.

Fig. 3 *Carpinus miocenica* TANAI. Hypotype, H.U.M.P., Reg. no. 26102. Ogawa.

Fig. 4 *Carpinus miofangiana* HU and CHANEY. Hypotype, H.U.M.P., Reg. no. 26015. Miyano loc. 2.

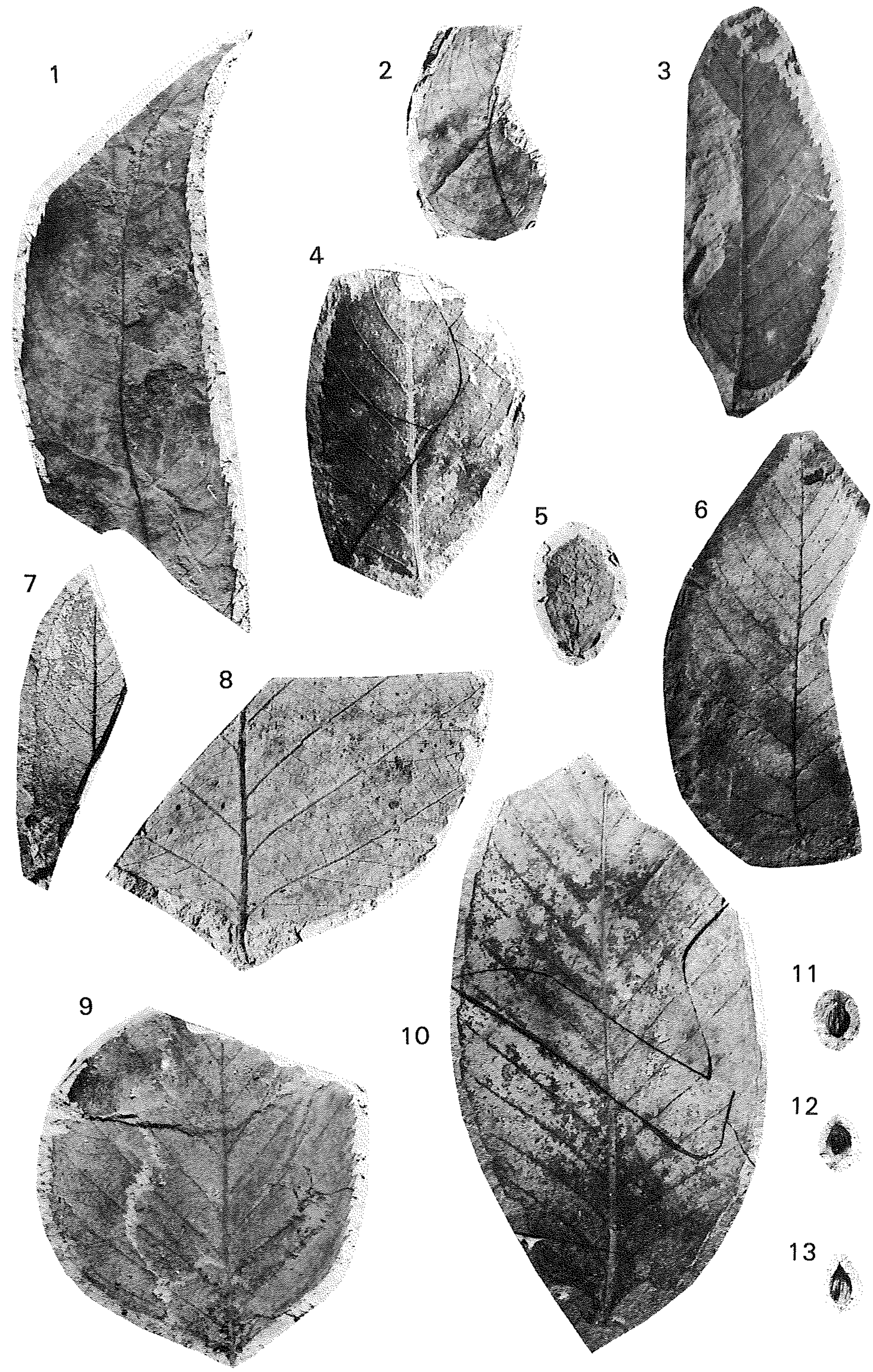
Figs. 5, 6 *Carpinus subcordata* NATHORST. Hypotypes, H.U.M.P., Reg. nos. 26103, 26104. Ogawa.

Fig. 7 *Pterocarya protostenoptera* TANAI. Hypotype, H.U.M.P., Reg. no. 26100. Ogawa.

Figs. 8, 9 *Alnus protomaximowiczii* TANAI. Hypotypes. H.U.M.P., Reg. nos. 26101. Ogawa. 26151. Kanagasawa loc. 2.

Fig. 10 *Fagus antipofi* HEER. Hypotype, H.U.M.P., Reg. no. 26152. Kanagasawa loc. 2.

Figs. 11-13 Carpinus subcordata NATHORST. Hypotypes, H.U.M.P., Reg. nos. 26105, 26106, 16107. Ogawa.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Explanation of Plate 3

Figs. 1, 2 *Carpinus subyedoensis* KON'NO. Hypotypes, H.U.M.P., Reg. nos. 26163, 26164. Miyano loc. 1.

Fig. 3 *Carpinus subyedoensis* KON'NO. Hypotype, H.U.M.P., Reg. no. 26108. Ogawa.

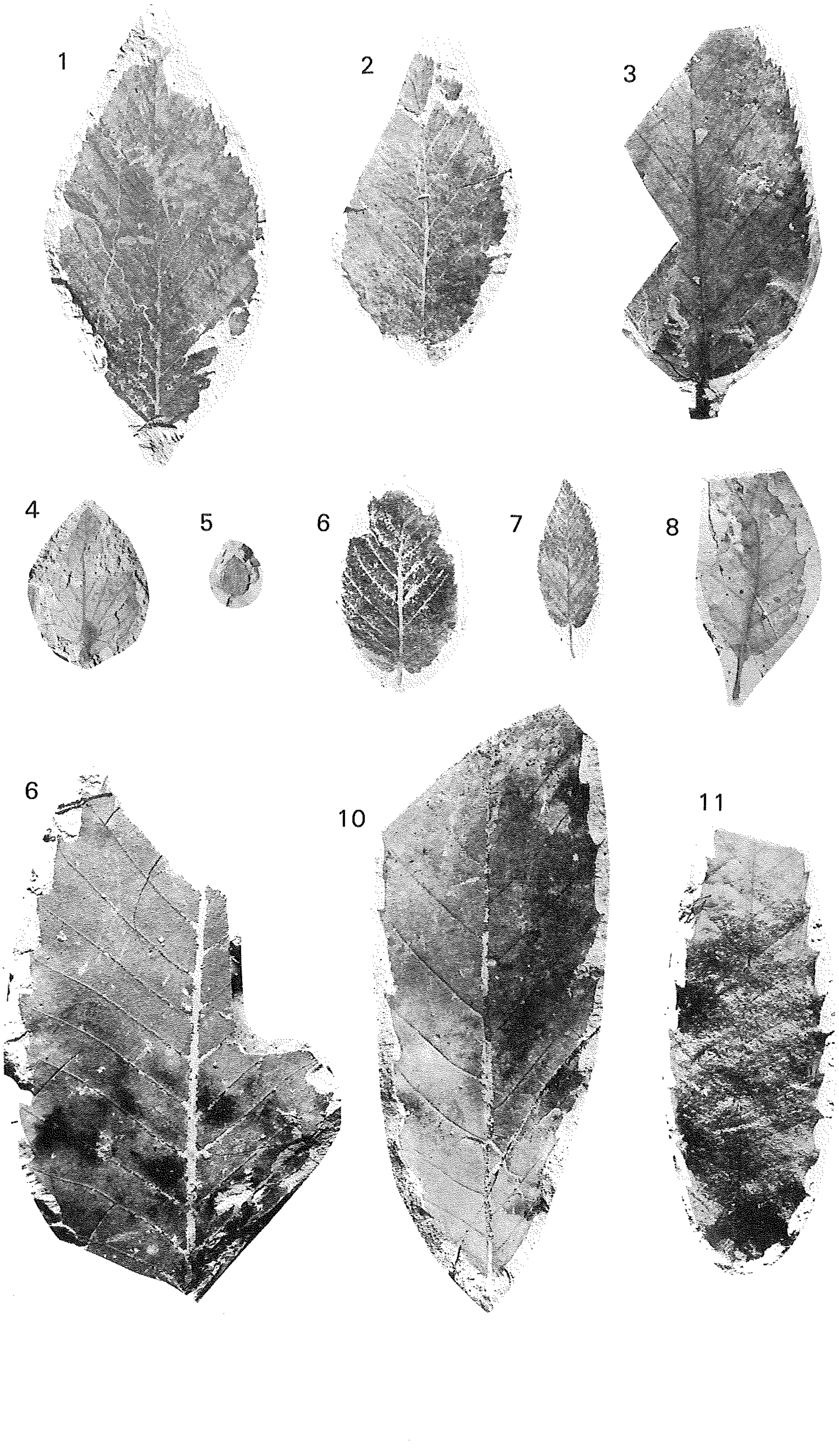
Figs. 4, 5 *Carpinus mioturczaninovii* HU and CHANEY. Hypotypes, H.U.M.P., Reg. nos. 26153, 26154. Kanagasawa loc. 2.

Figs. 6, 7 *Carpinus mioturczaninovii* HU and CHANEY. Hypotypes, H.U.M.P., Reg. nos. 26161, 26162. Miyano loc. 1.

Fig. 8 *Quercus miovariabilis* HU and CHANEY. Hypotype, H.U.M.P., Reg. no. 26155. Kanagasawa loc. 2.

Fig. 9 *Castanea miomollissima* HU and CHANEY. Hypotype, H.U.M.P., Reg. no. 26166. Miyano loc. 2.

Figs. 10, 11 *Quercus miovariabilis* HU and CHANEY. Hypotypes, H.U.M.P., Reg. nos. 26167, 26168. Miyano loc. 2.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Explanation of Plate 4

Figs. 1, 2 *Corylus macquarii* (FORBES) HEER. Hypotypes, H.U.M.P., Reg. nos. 26109, 26110. Ogawa. (fig. 2: x 2)

Figs. 3, 4 *Ostrya shiragiana* HUZIOKA. Hypotypes, H.U.M.P., Reg. nos. 26075. Garozawa; 26156. Kanagasawa loc. 2.

Fig. 5 *Ulmus carpinoides* GOEPPERT. Hypotype, H.U.M.P., Reg. no. 26116. Ogawa.

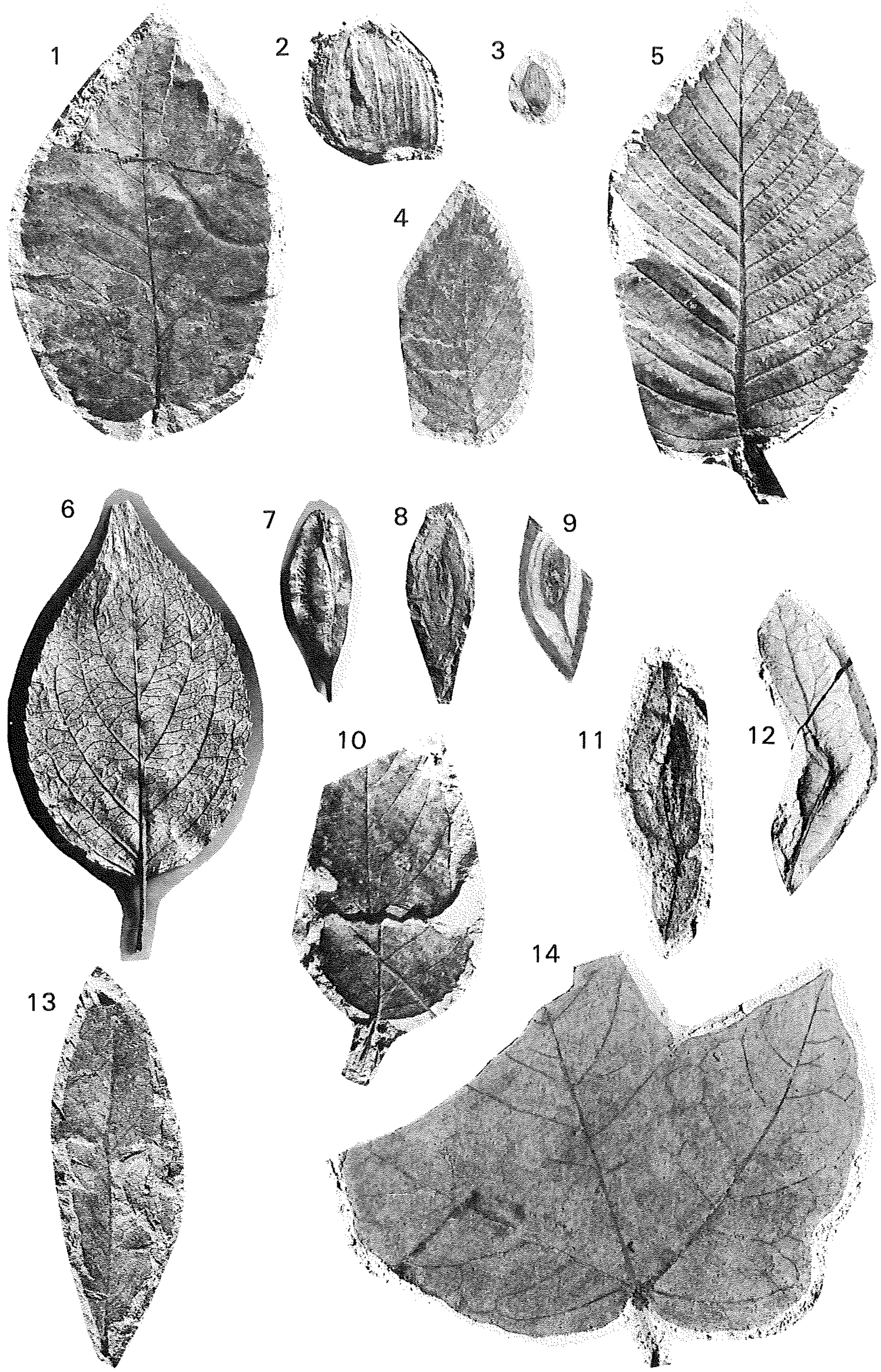
Figs. 6, 7 *Eucommia ulmoides* OLIVER. leaf and seed of the living species for comparison.

Figs. 8-11 *Eucommia japonica* TANAI. Hypotypes, H.U.M.P., Reg. nos. 26121, 26122, 26123, 26124. Ogawa. (fig. 11: x 2)

Fig. 12 *Tilia protojaponica* ENDO. Hypotype, H.U.M.P., Reg. no. 26140. Ogawa.

Fig. 13 *Gleditsia miosinensis* HU and CHANEY. Hypotype, H.U.M.P., Reg. no. 26125. Ogawa. x 2

Fig. 14 *Pueraria miothunbergiana* HU and CHANEY. Hypotype, H.U.M.P., Reg. no. 26126. Ogawa.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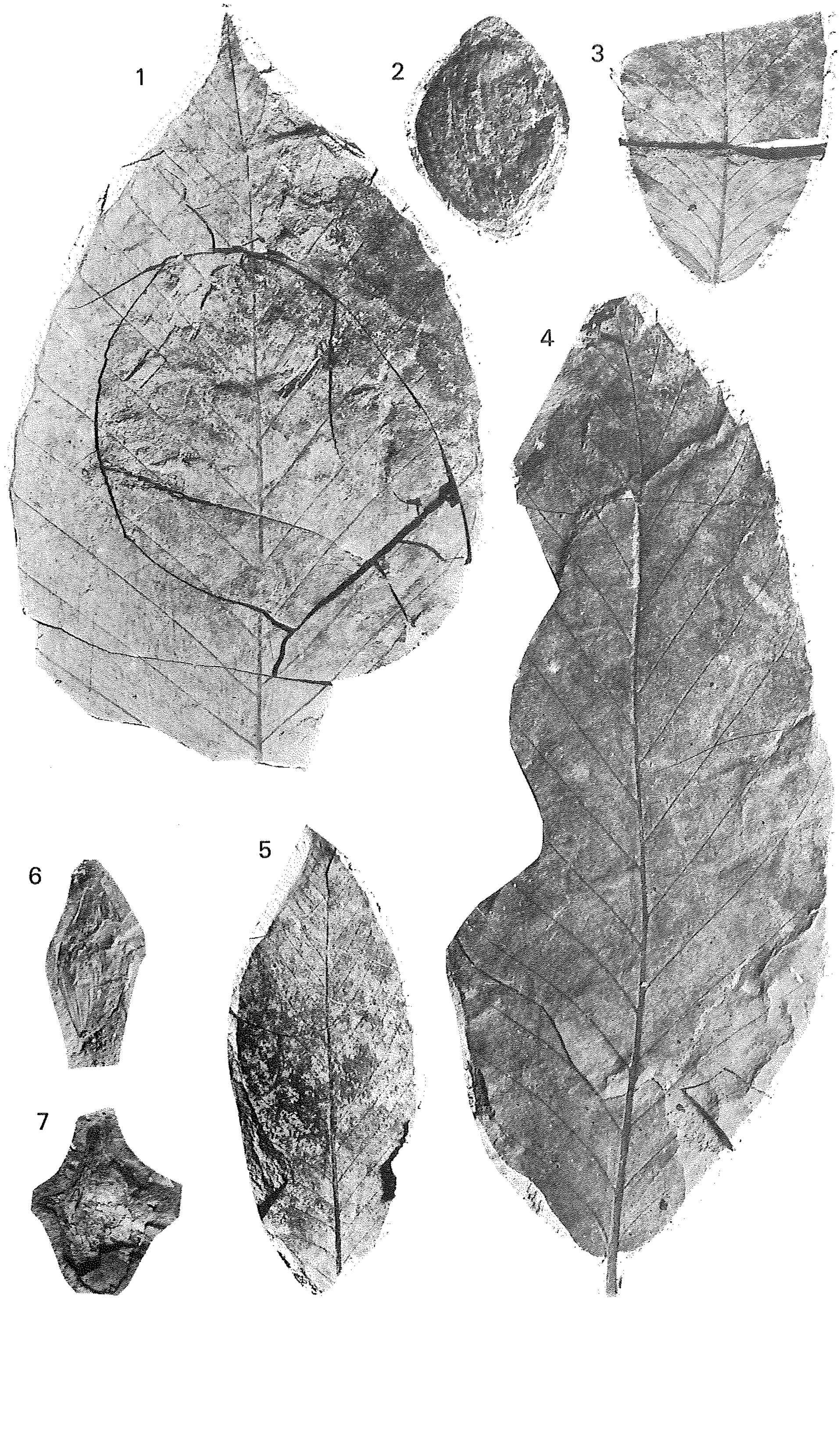
Explanation of Plate 5

Figs. 1-5 *Fagus antipofi* HEER. Hypotypes, H.U.M.P., Reg. nos. 26111, 26112, 26113, 26114a, 26115. Ogawa. (fig. 2: × 2)

Figs. 6, 7 *Hemitrapa borealis* (HEER) MIKI, Hypotypes, H.U.M.P., Reg. nos. 26141, 26142. Ogawa.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Explanation of Plate 6

Figs. 1-4 *Zelkova ungeri* KOVATS. Hypotypes, H.U.M.P., Reg. nos. 26117, 26118, 26119, 26120. Ogawa.

Fig. 5 *Phellodendron mioamurense* TANAI and N. SUZUKI. Hypotype, H.U.M.P., Reg. no. 26147. Kanagasawa loc. 2.

Figs. 6, 7 *Rhus miosuccedanea* HU and CHANEY. Hypotypes, H.U.M.P., Reg. nos. 26127a, b. Ogawa.

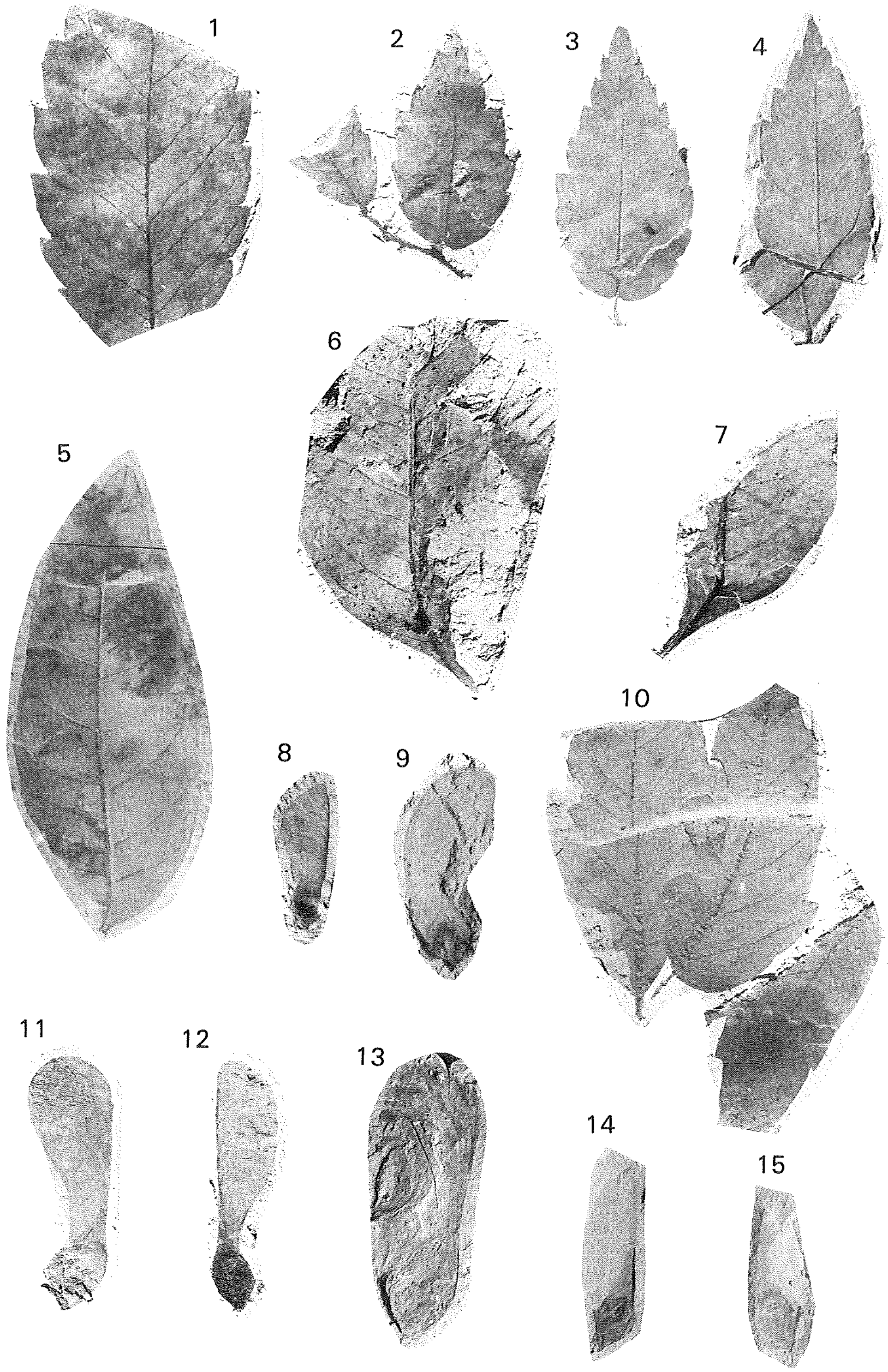
Fig. 8 *Acer protodistylum* ENDO. Hypotype, H.U.M.P., Reg. no. 26157. Kanagasawa loc. 2.

Fig. 9 *Acer prototataricum* TANAI and N. SUZUKI. Hypotype, H.U.M.P., Reg. no. 26158. Kanagasawa loc. 2.

Fig. 10 *Acer miohenryi* HU and CHANEY. Hypotype, H.U.M.P., Reg. no. 26159. Kanagasawa loc. 2.

Figs. 11-13 *Acer yoshiokaense* TANAI and N. SUZUKI. Hypotypes, H.U.M.P., Reg. nos. 26137, 26138, 26139. Ogawa.

Figs. 14, 15 *Acer pseudoginnala* TANAI and ONOE. Hypotypes, H.U.M.P., Reg. nos. 26160, 26169. Kanagasawa loc. 2.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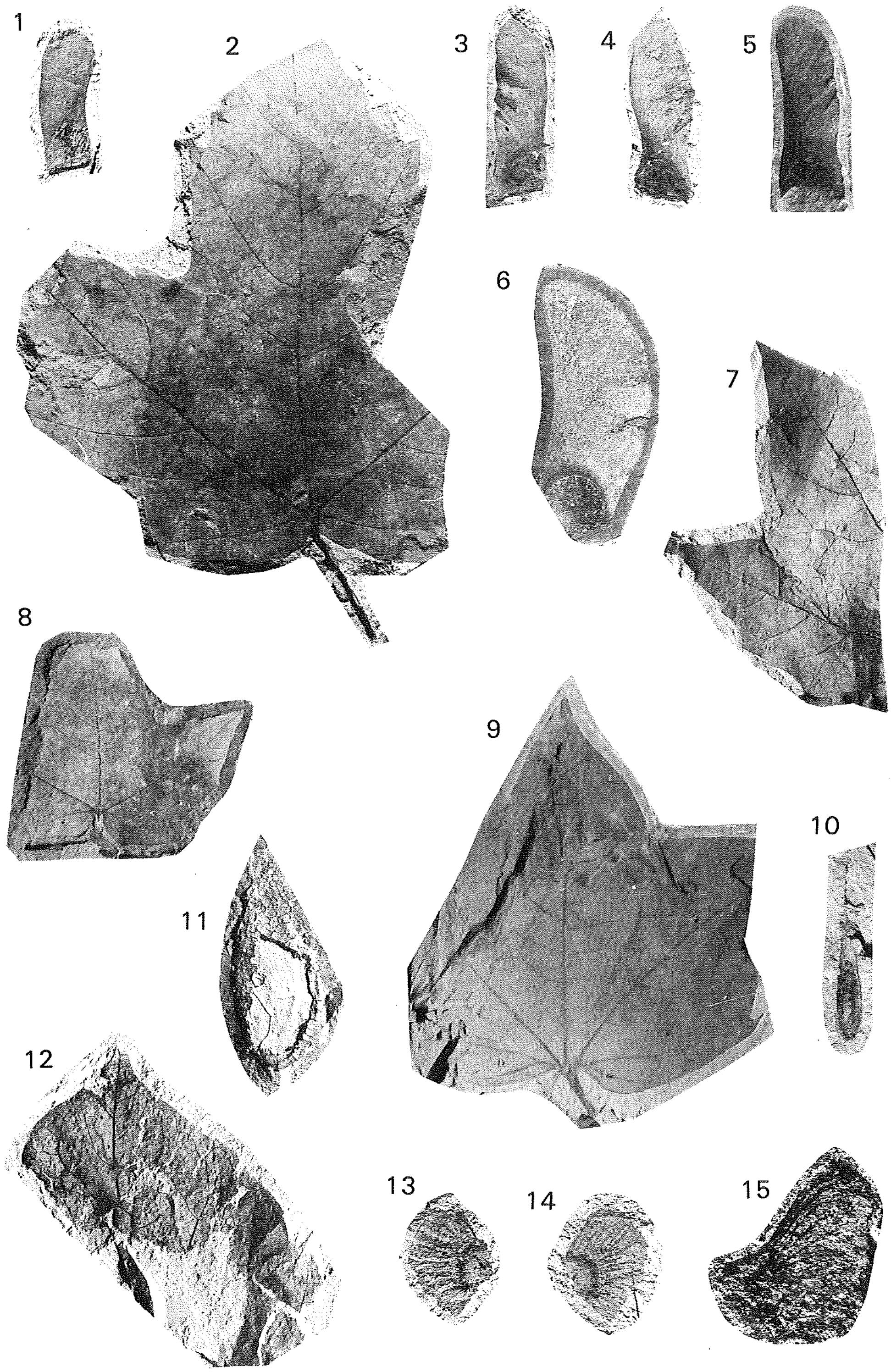
Explanation of Plate 7

Figs. 1-5 *Acer ezoanum* OISHI and HUZIOKA. Hypotypes, H.U.M.P., Reg. nos. 26128, 26114b, 26130, 26131, 26132. Ogawa.

Fig. 10 *Fraxinus wakamatsuensis* TANAI and N. SUZUKI. Hypotype, H.U.M.P., Reg. no. 26143. Ogawa

Figs. 11, 12 *Cercis miochinensis* HU and CHANEY. H.U.M.P., Reg. nos. 26144, 26170. Miyano loc. 1, 2.

Figs. 13, 14, 15 *Carpolithes japonica* (MORITA) ISHIDA. Holotype, H.U.M.P., Reg. nos. 26145a, b; 26146. Ogawa. (fig. 14: x 2)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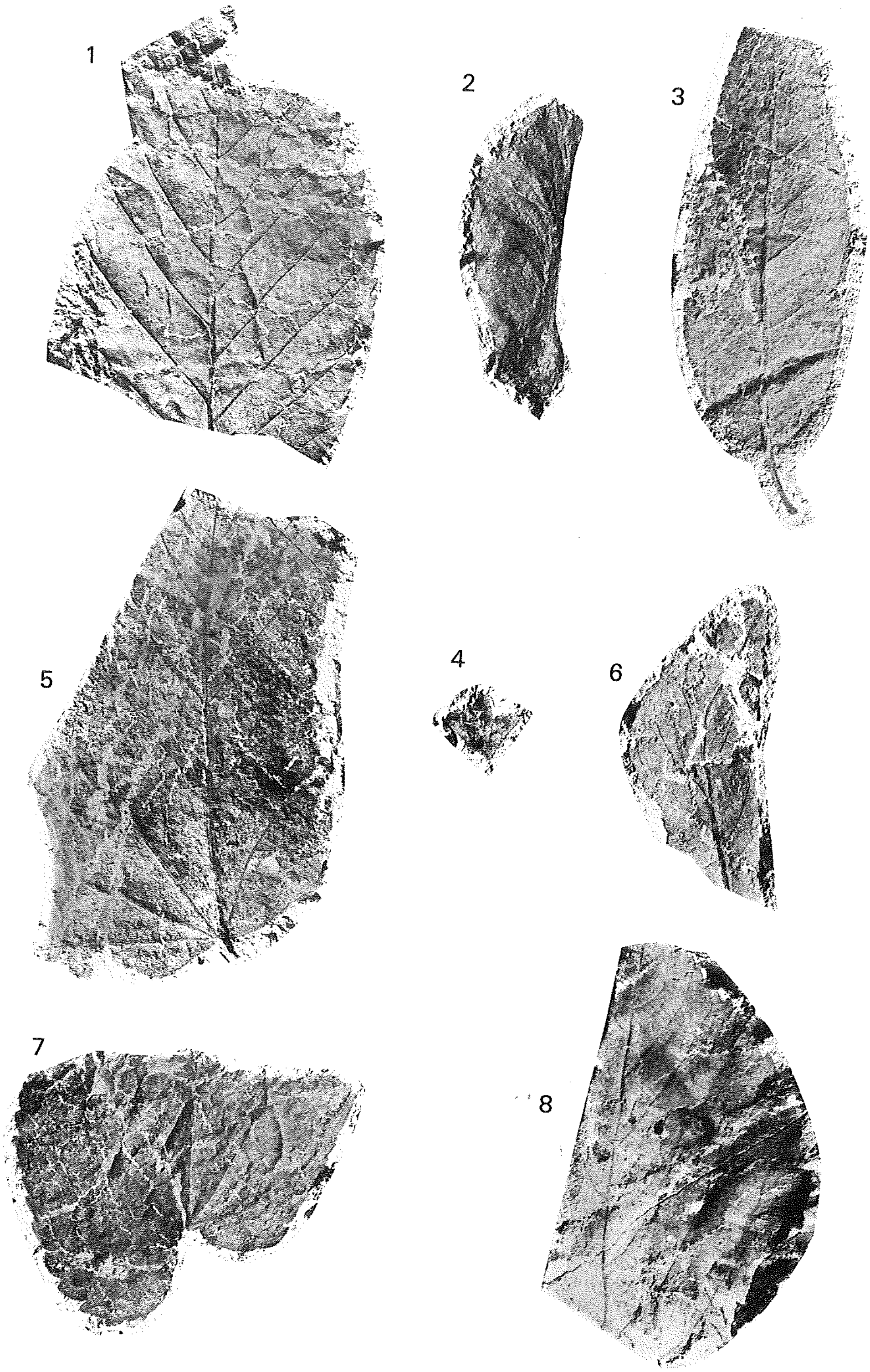
Explanation of Plate 8

Fig. 1 *Acer miodavidii* HU and CHANEY. Hypotype, H.U.M.P., Reg. no. 26076. Garozawa.
Fig. 2 *Acer subpictum* SAPORTA. Hypotype, H.U.M.P., Reg. no. 26077. Garozawa.
Fig. 3 *Salix miosinica* HU and CHANEY. Hypotype, H.U.M.P., Reg. no. 26073. Garozawa.
Fig. 4 *Trapa ezoana* TANAI and N. SUZUKI. Hypotype, H.U.M.P., Reg. no. 26082. Garozawa.
Figs. 5-8 *Tilia protojaponica* ENDO. Hypotypes, H.U.M.P., Reg. nos. 26078, 26079, 26080, 26081. Garozawa.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